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Executive control in speech comprehension: Bilingual dichotic listening studies

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Declaration

This dissertation is a presentation of my original research work and has not been submitted for any other degree or professional qualification. The work presented in this dissertation has been administered by myself. Wherever contributions of others are involved, every effort is made to indicate this clearly, with due reference to the literature, and acknowledgement of collaborative research and discussions. All analyses reported in this dissertation are original and were carried out by myself with a great amount of help from Dr. Mateo Obregon-Sargent.

Takayuki Miura

Tokyo, May 28, 2014

Abstract

In this dissertation, the traditional dichotic listening paradigm was integrated with the notion of working memory capacity (WMC) to explore the cognitive mechanism of bilingual speech comprehension at the passage level. A bilingual dichotic listening (BDL) task was developed and administered to investigate characteristics of bilingual listening comprehension, which include semantic relatedness, unattended language, ear preference, auditory attentional control, executive control, voluntary note-taking, and language switching. The central concept of the BDL paradigm is that the auditory stimuli are presented in the bilinguals' two languages and their attention is directed to one of their ears while they have to overcome cognitive and linguistic conflicts caused by information in the other ear. Different experimental manipulations were employed in the BDL task to examine the characteristics of bilingual listening comprehension. The bilingual population examined was Japanese-English bilinguals with relatively high second language (L2) proficiency and WMC. Seven experiments and seven cross-experimental comparisons are reported.

Experiment 1 employed the BDL task with pairs of passages that had different semantic relationships (i.e., related or unrelated) and were heard in different languages (i.e., L1 or L2). The semantically related passages were found to interfere with comprehension of the attended passage more than the semantically unrelated passages, whether the attended and unattended languages were the same or different. Contrary to the theories of bilingual language control, unattended L1 was found to enhance comprehension of the attended passage, regardless of semantic relationships and language it was heard in. L2 proficiency and WMC served as good predictors of resolution of the cognitive and linguistic conflicts. The BDL task is suggested to serve as an experimental paradigm to explore executive control and language control in bilingual speech comprehension.

Experiment 2 was conducted to investigate language lateralisation (i.e., ear preference) on bilingual speech comprehension, hence, the participants in Experiment 1 used their preferred ear, whereas participants in Experiment 2 used

their non-preferred ear, whether it was left or right, in the BDL task. Comprehension was better through the preferred ear, indicating that there is a favourable ear-to-hemisphere route for understanding bilinguals' two languages. Most of the participants were found to be left-lateralised (i.e., right-eared) and some to be right-lateralised (i.e., left-eared) presumably depending on their L2 proficiency and WMC.

Experiment 3 was concerned with auditory attentional control, and explored whether there would be a right-ear advantage (REA). The participants indicated an REA whether the attended and unattended languages were L1 or L2. When they listened to Japanese in the left ear, they found it more difficult to suppress Japanese in the right ear than English. WMC was not required as much as expected for auditory attentional control probably because the passages in Experiment 3 did not yield as much semantic competition as those in Experiment 1. L2 proficiency was crucial for resolving within- and between-language competition in each ear.

Experiments 4, 5, and 6 were replications of Experiments 1, 2 and 3, but these latter experiments considered the effect of note-taking that is commonly performed in everyday listening situations. Note-taking contributed to better performance and clearer understanding of the role of WMC in bilingual speech comprehension. A cross-experimental analysis between Experiments 1, 2, 4, and 5 revealed not only a facilitatory role of note-taking in bilingual listening comprehension in general, but also a hampering role when listening through the preferred ear.

Experiment 7 addressed the effect of predictability of language switching by presenting L1 and L2 in a systematic order while switching attention between ears and comparing the result with that of Experiment 6 where language switching was unpredictable. The effect of predictability of language switching was different between ears. When language switches were predictable, higher comprehension was observed in the left ear than the right ear, and when language switches were unpredictable, higher comprehension was observed in the right ear than the left ear, thereby suggesting a mechanism of asymmetrical language control. WMC was more related to processing of predictable language switches than that of unpredictable language switches.

The dissertation ends with discussions of the implications from the seven BDL experiments and possible applications, along with experimental techniques from other relevant disciplines that might be used in future research to yield additional insight into how bilingual listeners sustain their listening performance in their two languages in the real-life situations.

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CHAPTER 1: GENERAL INTRODUCTION

1.1 Focus of the dissertation

We tend to take listening for granted. Imagine, for example, that you are about to board a bus in a noisy street. You continue talking to a friend and listening to her replies; you understand when the driver, whose voice you have never heard before, tells you what the fare is; you notice that a small child on the bus has started crying; you realise that the music that had been blaring out of the clothes shop by the bus stop has been switched off. All this happens - or, more exactly, you accomplish all this - at the same time and without any noticeable difficulty...We only become aware of what remarkable feats of listening we achieve when we are in an unfamiliar listening environment, such as listening to a language in which we have limited proficiency. - Anderson & Lynch (1988, p. 3)

Comprehending a spoken language is comprised of processing several linguistic properties (i.e., phonology, syntax, semantics, and pragmatics) and analysing the coherence of what is being heard at the moment to what has been heard in the earlier discourse, then preparing to respond (e.g., Brown et al., 2000; Rost, 2002, 2011). This is already complicated, but it is even harder to listen to and comprehend a second language as described in the quote shown above.

Undertaking such a complex activity without misunderstanding in a second language (L2) requires a listener to have high working memory capacity (WMC), i.e., executive control, for resolving cognitive and linguistic conflicts from both the language not in use and the language in use at the moment (e.g., Flowerdew & Miller, 2005; Weber & Cutler, 2004). Executive control (e.g., Baddeley & Hitch, 1974; Engle & Kane, 2004; Kane & Engle, 2002) has been one of the core components in the recent research on bilingualism (e.g., Bialystok, 2009; Bialystok & Majumder, 1998; Emmorey et al., 2008). A strong link between executive control

and language control at the neurocognitive level has been recognised (e.g., Abutalebi et al., 2007; Crinion et al., 2006; Van Hueven et al., 2008), confirming that executive control is essential for bilingual language processing. This dissertation is dedicated to the exploration of the bilingual's cognitive mechanism underlying the governance of language control and cognitive control in speech comprehension.

Regardless of these groundbreaking findings, bilingual language control discussed in these previous studies has been entirely concerned with language production, and furthermore, language production was investigated only at the single-word level (Abutalebi & Della Rosa, 2012, p. 530). It has been often argued that the results in language production studies can be also applied to explaining language perception (e.g., Bialystok, 2009; Green, 1998; Lehtonen et al., 2005), which is debatable and for which more experimental verification is needed. Thus far, bilingual speech comprehension has been examined in the visual-world paradigm with an eye-tracker (e.g., Chambers & Cooke, 2009; Marian & Spivey, 2003a, 2003b; Mercier et al., 2014) and employed the brain imaging apparatus such as the event-related potentials (ERPs) and event-related functional magnetic resonance imaging (er-fMRI) (e.g., Abutalebi et al., 2007; FitzPatrick & Indefrey, 2010; Hahne & Friederici, 2001).

In the visual-world paradigm, participants hear an instruction to pick the target among four objects on the screen, for example, one of which has the same word-initial syllable (e.g., target: *marka* (stamp in Russian) vs. distractor: *marku* (an inflected form of *marka*) in the interlingual-distractor-present condition. There are another two experimental conditions: the interlingual-distractor-absent condition and within-language competition condition. The participants' eye movements after the instruction and the ratio of trials on which eye movements are made to the competitor object relative to a filler object as the dependent variable are recorded with the eye-tracker.

Although the visual-world paradigm may be useful for detecting effects of sentence context on lexical competition in bilingual listening comprehension (e.g., Dahan et al., 2002; Magnuson et al., 2008), there is no assurance whether such

indirect and implicit visual interference from another language resembles the interference from another language occurring in the bilingual mind when they hear one of their languages. Moreover, visual interference on both the visual and auditory target stimulus is in fact weaker than auditory interference on the auditory target stimulus (e.g., Latorella, 1998; Rees et al., 2001; Stanton et al., 1992), hence, it would seem that the degree of language competition observed in the visual-world paradigm is also weaker than language competition that could likely to be observed in the real-life listening endeavour.

In these two experimental paradigms, the auditory stimuli were either at the word or sentence level although the isolated words are least candidates for exploring language representation (Paradis, 2003) and listeners almost never hear phonemes in isolation, but larger linguistic units such as passages (Ingvalson et al., 2014). It should be also noted that actual listening comprehension should exploit all the available information provided by the context and it should express itself in purposeful activity by the listener, although the investigation on listening comprehension in the past concentrated excessively on the comprehension of isolated sentences (Dirven & Oakeshott-Taylor, 1985). Therefore, it was thought necessary to create a task that could investigate concurrent (both auditory) language competition and the mechanism of inhibition of another language taking place during listening at the passage level. The dichotic listening task (e.g., Asbjørnsen & Hugdahl, 1995; Broadbent, 1952, 1954, 1958; Bryden et al., 1983; Cherry, 1953; Hugdahl, 2003; Hugdahl et al., 2009) was considered to be able to tackle these questions at once. In Chapter 3, I present a bilingual dichotic listening (BDL) task in which pairs of passages with same and different semantic relationships and in two languages are heard as a new experimental paradigm to achieve the above-mentioned purpose.

How a bilingual's languages are represented in the brain has drawn much attention in the bilingualism research, although it is still controversial (Herdina & Jessner, 2002) because bilinguals' lateralisation patterns seem to be influenced by the nature of the input stimuli and the direction of translation (García, 2013). Early bilinguals show a similar lateralisation pattern to that of monolinguals in the DL task,

whereas late bilinguals show a more left lateralised pattern (e.g., Morton et al., 1998). The degree of similarities between the bilingual's two languages also seems to influence the lateralisation pattern (D'Anselmo et al., 2013). Professional simultaneous interpreters show different lateralisation patterns depending on their experience in simultaneous interpreting and preferences for processing one language relative to another (e.g., Fabbro et al., 1991; Gran & Fabbro, 1989; Hamers et al., 2002; Lambert, 1993; Proverbio & Adorni, 2011; Spiller-Bosatra et al., 1990). Chapter 4 will further advance these previous studies in the BDL task.

Bilingual advantage (although monolinguals are not included as a control group in this dissertation) that has been demonstrated in the DL task includes not only better recall of the relevant stimuli but also auditory attentional control (e.g., Hugdahl et al., 2009; Soveri et al., 2011), i.e., maintenance of their attention to the relevant information and suppression of the task-irrelevant information (e.g., Engle, 2010, Engle & Kane, 2004). There has been a right-ear advantage (REA) reported in these DL studies indicating a general tendency to recall an auditory verbal stimulus from the right ear more often than from the left ear (e.g., Bryden, 1963, 1988; Hugdahl, 1995). Results from these studies are not generalisable to the actual speech comprehension behaviour among bilinguals as the auditory stimuli that have been investigated are pairs of syllables, words and sentences (e.g., Filippi et al, 2012; Hugdahl et al., 2009; Soveri et al., 2011). Hence, it is unsure if bilinguals can withstand passage-level interference that takes place in the everyday situation and show a similar behaviour when comprehending passages to that of when they perceive syllables, words and sentences. Furthermore, in light of the fact that it is more cognitively demanding to recall from the left ear while ignoring the right ear stimulus than vice versa among healthy individuals and even more demanding among patients (e.g., schizophrenic and Parkinson's disease) who are cognitively disadvantaged (e.g., Bryden, 1963; Hugdahl, 2003; Kimura, 1967), and the BDL stimuli are presented in two different languages, the left ear may also show more difficulty in recalling content and inhibiting another language than in the right ear. I will examine these issues in the BDL task in Chapter 5.

How a bilingual is engaged in speech comprehension in her two languages while switching between them in the *real-life* situation has been hitherto explored at the phoneme, word, and sentence levels in noise (e.g., Black & Hast, 1962; Bradlow & Bent, 2002; García Lecumberri & Cooke, 2006; García Lecumberri et al., 2010; Meador et al., 2000; Quené & van Delft, 2010). The noise includes both linguistic and non-linguistic stimuli, each coming from one of two or three loud speakers (not headphones, so the stimuli are blended in the air). What listeners usually do involves not only hearing several talkers at the same time, but also voluntary note-taking when listening to lengthy speech stimuli such as passages (e.g., Carrell et al., 2002; Lin, 2006; Piolat et al., 2005). Listeners take notes when it is necessary to do so for later use of the notes such as when making purchases, planning future events and activities, studying for examinations, and preparing a technical talk, and for various reasons (Piolat et al., 2005). The cognitive mechanism of bilingual speech comprehension of passages in the pseudo-real-life situation in the BDL task in which voluntary note-taking is considered is examined in Chapter 6 by showing replications of the former three experiments.

Difficulty in language switching has been found to be influenced by the predictability of language switches, that is, predictable switches require less cognitive resources than unpredictable switches (e.g., Chee, 2009; Meuter, 2005; Meuter & Humphreys, 1997; Price et al., 1999). In the forced-attention DL task (e.g., Hugdahl, 1995; Soveri et al., 2011), the attended ear was designated by the cue, and was therefore predictable, but the attended stimulus, whether a syllable or a sentence in one of the two languages (e.g., Filippi et al., 2012), was not known before presentation, and was therefore unpredictable. A seventh experiment presented in Chapter 7 examines the effect of predictability of language switches in the BDL task.

Throughout this dissertation, executive control is considered as one of the most crucial constituents that underlies bilingual speech comprehension. Bilingual listeners are often confronted with both intra- and interlanguage competition at all linguistic levels (e.g., Blumenfeld & Marian, 2007; FitzPatrick & Indefrey, 2010; Marian & Spivey, 2003a, 2003b; Spivey & Marian, 1999; Weber & Cutler, 2004). To

overcome these interruptions and accomplish a task in a language in use at the moment, executive control is vital (e.g., Abutalebi et al., 2000; Crinion et al., 2006; Ye & Zhou, 2008, 2009a) since executive control deals with monitoring and resolving conflicts by inhibiting the activation of unwanted information in conditions that are complex, full of distractions, or that lead to response competition (e.g., Feldman-Barret et al., 2004; Osaka et al., 2004; Rodriguez-Fornells, et al., 2006; Wang et al., 2009). On that account, executive control, i.e., working memory capacity (WMC) (e.g., Baddeley & Hitch, 1974; Meier & Kane, 2013), is estimated in all experiments and discussed while referring to the roles of executive control in bilingual speech comprehension.

1.2 Organisation of the dissertation

This dissertation is presented in a way that it gives answers to the principal question: How are bilinguals capable of maintaining listening comprehension in each of their languages? Seven experiments employed the new bilingual dichotic listening (BDL) task with systematically different experimental manipulations to show answers to the question from each perspective of semantic relatedness, unattended language, ear preference, auditory attentional control, executive control, voluntary note-taking, and language switching, all of which are constituents of bilingual listening comprehension.

Chapter 2 presents the literature review. Throughout this dissertation, bilingual listening comprehension is considered as a cognitive process in which bilinguals control their attention to and comprehend one of their languages while overcoming inadvertent interruptions from another language. Six relevant areas of study are reviewed: language comprehension and cognitive control, bilingualism, working memory, language control, auditory attentional control, and note-taking. These areas of study are fundamental for points of interest investigated in Chapters 3, 4, 5, and 6. Chapter 2 ends with a contrastive view of Japanese language with English language and an overview of the seven experiments.

In Chapter 3, I propose the BDL task as a new experimental paradigm to explore the cognitive mechanism of bilingual speech comprehension. One experiment with the BDL task that investigated the bilinguals' language and cognitive control in speech comprehension of meaningful passages is presented. In the BDL task, there were both semantic and linguistic interference from the unattended channel that had to be efficiently inhibited. I demonstrate contrary findings to the previous studies and theories that L1 is easier to inhibit than L2. I also maintain that the BDL task serves as an experimental paradigm to investigate executive control and language control in bilingual speech comprehension.

Chapter 4 presents an experiment that was a replication of the first experiment to explore the effect of ear preference for speech comprehension among bilinguals. Thus, participants in the first experiment used their preferred ear and those in this experiment used their non-preferred ear in the BDL task. I show some evidence of language lateralisation among bilinguals for cognitive control and language control in speech comprehension.

Experiment 3 described in Chapter 5 probed the degree of ear advantage for comprehension of one language while there is another competing language. Previous dichotic listening studies on both monolinguals and bilinguals consistently demonstrate a right-ear advantage (REA) for processing speech stimuli. I present that the REA is found among bilinguals for controlling attention to one language and inhibiting both within- and between-language competition.

Chapter 6 illustrates three experiments that are replications of the first three experiments considering the role of note-taking to elucidate the cognitive mechanism of bilingual speech comprehension in the real-life listening situation. Cross-experimental analyses between the first three experiments that did not consider note-taking and the latter three experiments that considered note-taking are presented. As note-taking can be beneficial under some conditions, but can be disruptive under other conditions, it was expected to see whether note-taking could be beneficial for bilingual speech comprehension in the BDL task. The findings confirm that voluntary note-taking is beneficial for maintenance of attention to one language and

inhibition of another language, leading to better understanding of the cognitive mechanism of bilingual speech comprehension.

A seventh experiment examining the effect of predictability of language switching is presented in Chapter 7. The attended language was presented in a random (i.e., unpredictable) order throughout the former six experiments, but it was presented in a systematic (i.e., predictable) order, i.e., from L1 to L2 and from L2 to L1, while the attended ear was also systematically switched in the seventh experiment. I outline a cross-experimental analysis between Experiment 6 and Experiment 7, and the results that showed no effect of predictability of language switching.

Chapter 8 summarises the results of the analyses in the seven experiments and those in seven cross-experimental analyses, and shows their implications and suggestions for potential future investigations.

1.3 Collaborations and presentations

Some of the experiments presented in this dissertation are based on collaborative work and have been presented at conferences.

Experiment 4 in Chapter 6 is based on a manuscript by Takayuki Miura, Martin J. Pickering, Robert H. Logie, and Antonella Sorace. A part of it has been presented at the 5th International Conference on Memory in 2011 (University of York, England).

Experiment 6 in Chapter 6 is based on a manuscript by Takayuki Miura, Martin J. Pickering, Robert H. Logie, and Antonella Sorace. A part of it has been presented at the 37th Annual Convention of Japan Society of English Language Education in 2011 (Yamagata University, Japan).

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Understanding language processing may involve investigations on what is produced (speaking and writing) and what is perceived (reading and listening) from viewpoints of so-called theoretical linguistics such as phonology, syntax, semantics, and pragmatics. Language is also studied from a social perspective in sociolinguistics which investigates the relationship between language and society (Yule, 2010, p. 254). Psycholinguistics, whose history is derived from Greek philosophers such as Plato (Garnham et al., 2006, p. 1), examines language with its central goal of exploring psychological mechanisms of language use in the two domains of production and comprehension (*ibid.*, p. 8). With the advent of neuroimaging techniques such as fMRI, PET or MEG and ERP, it has become possible for cognitive neuroscientists to scrutinise the relationship between biology and behaviour, that is to understand how the brain operates to control and carry out all aspects of cognition (Cutler et al., 2005, p. 8). Among these fields of study which deal with language processing, psycholinguistics is the one that can tackle questions from two disciplines, linguistics (why is language the way it is?) and psychology (how do humans process language?) (Cutler et al., 2005, p. 2), thereby enabling psycholinguists to grasp the language phenomena more precisely from not only one, but various perspectives, utilising empirical methods established in cognitive and experimental psychology, neuroscience and neuropsychology. Psycholinguists investigate typical healthy adults as well as children, elderly, and patients with language-related disorders in the brain. Psycholinguistic approaches have been applied in other related fields such as *second language acquisition* (e.g., Felser, 2005; Segalowitz & Lightbown, 1999) where the way second language learners process the target language in real time is examined; *aphasia* (e.g., Geschwind, 1971; Green, 1969), where how humans perceive, understand and transmit messages is studied, which is later called neurolinguistics (e.g., Dingwall & Whitaker, 1974;

Ingram, 2007; Whitaker, 1971); *autism* (e.g., Pierce & Bartolucci, 1977; Tager-Flusberg, 1985) where differences and similarities in language development (i.e., phonological, semantic, syntactic, and pragmatic) between autistic and normal children, and language and communication problems of autistic children are explored; and *bilingualism* (e.g., Bialystok, 1997, 1999, 2001, 2005, 2009; Colzato et al., 2008; de Groot, 2011; de Groot & Kroll, 1997; Hull & Vaid, 2007; Grosjean & Li, 2013; Kroll & de Groot, 2005; Vaid & Hall, 1991) which investigates the psychological mechanism of language production (speaking and writing) and comprehension (reading and listening) among bilinguals who speak two or more languages, consequences of bilingualism on cognition, and the bilingual brain, most of which are the topic of the dissertation.

Language processing studies in the above-mentioned fields have put their focus on language behaviours among monolingual speakers. An exception is that testees in applied linguistics are almost always second language (L2) learners, since the field is the study of language learning and language teaching of L2. De Groot (2011, p. 3) critically points out that among others even psycholinguistics is characterised by a strong monolingual bias and researchers might just ignore or take for granted the fact that their participants are speakers of one or more other languages, which may have an impact on the way each of their languages is mentally represented and processed. Consider also the claim that the number of people who speak two or more languages is over 50% (Fabbro, 1999; Grosjean, 1982) or as high as 80% of the world population (Porch & Berkeley-Wykes, 1985), although the levels of proficiency among individuals vary and definitions of bilinguals are not consistent among researchers. It would be rather logical and, moreover, intriguing to investigate language processing, not only from the monolingual-psycholinguistic point of view, but also from the bilingual-psycholinguistic perspective, so as to explore cognitive mechanisms of language processing and how knowledge of some other languages influences the way language currently in use is processed (de Groot, 2011, p. 3).

Bilingualism has been shown to have far-reaching implications for cognitive processing beyond the realm of language (Cutler et al., 2005, p. 9), such as shown in

a study by Bialystok et al. (2004) where they used a perceptual-motor task called the Simon task (Simon & Wolf, 1963). In the task, the bilingual participants were required to quickly and accurately respond to colour stimuli, for example blue and red, which were positioned on either the left or right side of a computer screen. The participants were instructed to press a key on the left-hand side of the keyboard if the presented colour was blue, and to press a key on the right side if the presented colour was red. There were two experimental conditions: *congruent* and *incongruent*. In the congruent condition, the position of the colour on the screen and the position of the key to be pressed matched, but in the incongruent condition, the colour position and key position did not match. Trials in these two conditions were counterbalanced, so they were presented in a randomised order. The authors found that when compared with age-matched monolinguals the bilingual participants who maintained two languages and were engaged in language switching between them throughout their lives (there were a younger age group (*Mean* age: 43.0) and an older age group (*Mean* age: 71.9)) demonstrated more efficient cognitive control and inhibition even in the non-linguistic Simon Task, namely showing smaller Simon effect (i.e., smaller response time differences between the incongruent and congruent conditions). The bilingual's so-called cognitive control advantage in general cognitive processes, e.g., executive attention (Engle, 2002), and conflict resolution (e.g., Miller & Cohen, 2001, p. 170), has been confirmed through childhood to adulthood with many other cognitive non-linguistic tasks such as the Stroop task (Stroop, 1935), the attentional network task (Fan et al., 2002), the dimensional change card sort task (Bialystok & Martin, 2004), and the flanker task (Eriksen & Eriksen, 1974). Hence, it seems reasonable to take bilingualism into account when researching language processing.

There is another field of study that has to be added to achieve the purpose of the current research, that is working memory (WM) (Baddeley & Hitch, 1974). Ever since its onset, the notion has gathered much attention and been examined in a large number of behavioural and cognitive science studies such as in reading comprehension (e.g., Daneman & Carpenter, 1980), amnesia (e.g., Richardson-Klavern & Bjork, 1988), first language acquisition (e.g., Gathercole & Baddeley,

1989), cognitive inhibition (e.g., Engle et al., 1999), attentional control (e.g., Conway & Engle, 1994; Osaka & Osaka, 2007), and cognitive mechanism in the brain (e.g., Osaka et al., 2007). An estimate of working memory capacity (WMC) (Engle et al., 1999) has also been widely employed as a measure of executive functioning and control (e.g., Conway et al., 2001; Hamilton & Martin, 2007). As language comprehension is an activity which entails the process of selecting, organising, and integrating information (Imhof, 2004), it requires a functioning self-regulatory system with comprehensive attention and WMC, especially in listening comprehension (Janusik, 2004), since the relevant stimuli are temporally distributed, which means that they are transient and not available for further reference (Imhof, 2010, p. 98). Taking into account the role of WMC in bilingual speech comprehension would be an aid and lead to the understanding of its cognitive mechanism.

This dissertation puts an emphasis on the investigation of the cognitive mechanism of language comprehension, exclusively speech comprehension among bilinguals, as this is the least researched aspect of bilingualism (Filippi et al., 2012), which involves language control (e.g., Green, 1998) and executive control (e.g., Bialystok, 1999). More precisely, the current dissertation aims to demonstrate how bilingual listeners resolve cognitive and linguistic conflicts occurring in continuous speech in either or both of their two languages and to investigate what kind of cognitive and experiential factors would be accountable for this ability. The current research is an integration of the three approaches mentioned above: psycholinguistics, bilingualism and WM. It is hoped that findings from the current research will contribute to the better understanding of the cognitive mechanism of bilingual speech comprehension, i.e., the field of study that has not drawn much attention, but has much room to flourish. Speech comprehension means an understanding of, not words or sentences, but meaningful passages, which any language speaker perceives in a daily communication. Paradis (2003) asserts that there is no rationale for generalisation from single-word processing to the whole language processing, which is principally true of individual words out of context, and

that the isolated words are least candidates for exploring language representation. Furthermore, Graesser et al. (1997, p. 164) maintain that a sentence out of context is nearly always ambiguous, whereas a sentence in a discourse context is rarely ambiguous.

On these accounts, the dissertation attempts to probe cognitive processes that are involved in bilingual speech comprehension principally at a *meaningful passage level*, which are usually heard in one of the bilingual's languages with occasional switches between them. Hearing passages in only one of their languages requires inhibition of the other language, and it is often the case that the typical listening environment involves some other irrelevant information such as sounds of vehicles, wind, rain, and other people talking in the background. In order to empirically investigate bilingual speech comprehension in such a real-life situation, the following experimental manipulations to listening stimuli have been made to create a pseudo-real-life listening condition: 1) participants simultaneously hear two auditory stimuli, one in each ear, but attend to only one of them; 2) the auditory stimuli are either semantically related or unrelated; 3) the auditory stimuli are either in the same language or different languages; 4) the attended ear is switched from left to right or from right to left; and 5) the language of the attended stimulus switches from one to another.

This literature review is organised in the following manner. Section 2.2 presents the concept that language comprehension involves not only processing of linguistic units such as phonemes, words, syntax or sentences, but also suppression of irrelevant, both linguistic and non-linguistic information surrounding the comprehender. Section 2.3 reviews the bilingualism literature with its primary focus on language use, psycholinguistic investigations on bilinguals' speech comprehension, and recent findings of and the model of bilingual language processing. Section 2.4 reviews research on WM, especially from the viewpoint of auditory processing, and its role in language comprehension, and shows how cognition works in controlling what enters memory when processing linguistic information and the relationship between language processing and executive control

of attention. In Section 2.5, attention is directed to more specific mechanism of language control, the selection and inhibition of language, the mechanism of language switching and how it is represented in the brain. Language control is further described in relation to how the brain achieves the endeavour. Section 2.6 deals with attentional control, principally, in auditory processing, and gives an overview of the historic research on cocktail party effect, monolingual and bilingual behaviours in auditory attentional control, another historic research with the dichotic listening (DL) task, the experimental paradigm adopted in the investigation of the research question, and how auditory processing is lateralised in the brain. Section 2.7 gives a description of the application of and mechanism of note-taking as a memory aid, which is not considered in traditional cognitive psychology, but seen frequently in various everyday situations. Section 2.8 gives a contrastive view of Japanese language, which is the first language of the current bilingual participants, with English language, which is their second language.

Much research on bilingual speech processing has been conducted on bilinguals of Indo-European languages such as Dutch, Spanish, French, and Italian as their first languages, and English as their second language, and much attention has been paid to whether bilinguals process their second language (e.g., English) the same way as their monolingual peers. Although growing in number, there has been still much less investigation on bilinguals of non-Indo-European languages such as Japanese, as their first language. Japanese is in fact an Altaic language which is characterised by agglutination and vowel harmony. There are no grammatical number, gender or articles in Japanese. The Japanese word order is not as strict as that of English that has a basic subject-verb-object structure. Japanese has a basic subject-object-verb structure and the word order is rather free. A Japanese sentence can be complete with a single verb or adjective (e.g., “*Shitteru?*” [Do you/Does she] know (it)?” or “*Kireida!* [You are/She is/It is] beautiful!”). Japanese can be written in more than one script: *Kana*, a phonologically-based system (there are *hiragana* (e.g., あ /a/) and *katakana* (e.g., ア /a/) for different contexts) and *kanji*, a symbol system derived from Chinese characters and more lexically-based (e.g., 日本 /nihon/ (Japan)) (Obler et al.,

2007, p. 35). English is a stress-timed language, whereas Japanese is a mora-timed language. It must be notoriously known that Japanese listeners have difficulty in both producing and distinguishing between /l/ and /r/ (e.g., Sheldon & Strange, 1982), so they cannot identify whether they heard *long* or *wrong*, or *light* or *right* when they are presented individually.

Research on bilingual language processing at a sentence-level shows that the second language puts greater demands on memory and attention than the first language, and that it is even true of reasonably proficient bilinguals (e.g., Miyake & Friedman, 1998). Although much insight on bilingual speech processing has been earned from bilinguals of Indo-European languages, it remains uncertain whether conclusions drawn from them are germane to speech processing of those who speak one Indo-European language (English) and one non-Indo-European language (Japanese) which has these many linguistic differences. Languages with syntactic, morphological, and phonological differences are likely to influence the ease of cross-language comprehension (Schwartz & Kroll, 2006, p. 987). It has been recently revealed that even highly proficient bilinguals briefly gain access to their first language when hearing words in the L2 (e.g., Thierry & Wu, 2007). Hence, it would be likely that processing meaningful-passage-level stimuli in one of the bilingual's two languages requires faster access, and stronger and ceaseless attention to the language for comprehension to obtain semantic and syntactic information, and suppression of any unwanted information from the other language simultaneously, because the stream of speech is uncontrollable and fades away quickly. The present research specifically aims to investigate to what extent these different languages influence comprehension of each other when processing passages. Lastly, Section 2.9 concludes with a summary of the literature review and an overview of experiments.

2.2 Language comprehension intertwined with cognitive control

This section provides a general view of listening comprehension in cognitive psychology of monolingual and normal-hearing listeners. The latter part provides a

brief overview of research on the relationship between language comprehension (speech perception) and cognitive control. The section ends with a statement as to applications of methodologies, used in research on cognitive control in speech comprehension, to investigations of the cognitive mechanism of listening comprehension among bilinguals.

There has been much more research on comprehension processes in reading than in listening to speech (e.g., Alexander & Jetton, 2003; Cutler & Clifton, 1999, p. 123). Researchers claim that studies in reading and listening have demonstrated comparable outcomes when the target language was a first language of their participants (e.g., Kintsch & Keenan, 1973) and what is generally true of reading is also generally true of listening to speech (Cutler & Clifton, 1999). There are common features between readers and listeners, in that they arrive at a semantic interpretation of a sentence in an apparently-incremental and nearly-immediate manner (Cutler & Clifton, 1999, p. 142). Both readers and listeners do not wait until the end of a clause or sentence, but they appear to accumulate their understanding of a sentence as they read and hear it. Notwithstanding, an obvious difference between the two skills lies in their modalities, auditory or written text perception, which makes the way comprehension is carried out in each skill different. Lund (1991) states that a decade between 1980 and 1990 has brought increasing awareness that listening is a set of skills in its own right and that reading research may not automatically transfer to listening. Since then, extensive research has been conducted on whether reading and listening are different as for how information is processed in each modality (e.g., Bradley & Foster, 1987; Cohen, 1993; Neumann et al., 1986). Research findings indicate that there are a wide range of modality-specific effects and mental activities, which are unique to listening (Buck, 2001, p. 31), and that there are functional differences between visual and auditory information processing on perception, word recognition, sentence parsing, and discourse comprehension (Imhof, 2010, p. 115).

On these accounts, it appears important to realise that listening and reading are not identical twins, but listening is another cousin with specific characteristics from the language skills family (Imhof, 2010, p. 116). Hence, it does not seem to be

appropriate to present language comprehension studies from the reading point of view. For this reason, the following part of this section seeks to introduce processes in language comprehension solely from the listening point of view.

Difficulties in listening compared to reading are first presented in order to differentiate these two skills and highlight cognitive processes involved in listening. Compared to the situations readers may find themselves when reading, listeners seem to be faced with potentially more problems due to the nature of stimuli. In reading, each word can be seen as a whole, whereas a spoken word is spread out in time and is transitory. Cutler and Clifton (1999, p. 144) show two challenges a listener has to face. One is that words in a sentence are not physically separated as those in reading. Identifying phonological words is a process which involves a process of estimating lexical units and boundaries within larger phonological groupings (Cutler & Broersma, 2005). Another challenge is derived from the ephemeral nature of human speech. It is not possible for a listener to listen back to what she has just heard in the way a reader can go back a few words before to confirm her understanding. Brown, van Berkum, and Hagoort (2000) state that both the diversity of linguistic and non-linguistic knowledge sources and the speech rate place particular demands on the listener. Within a fragment of a second, all the necessary linguistic features (phonological, syntactic and semantic) embedded in the speech stream have to be activated and examined upon the earlier lexical, sentential, and discourse information. During everyday speech communication, listeners must cope with a variety of competing noises in order to understand their interlocutors (Van Engen, 2010). Thus, it would be conceivable that, compared to readers, listeners are usually confronted with more obstacles to handle, which are uncontrollable and unforeseeable.

While overcoming these hurdles, listeners have to process linguistic components in the continuous speech at the right rate to understand whatever the interlocutor says at her own choice of volume and speed. As a normal speaking rate has approximately eight words per every two- to three-second burst of speech, word recognition in speech must take place very quickly in speech comprehension. Achieving this

requires multiple sources of information contributing to word recognition (Rost, 2002, p. 21).

Two of the most well respected models which have attempted to explain about word recognition are the cohort model (Marslen-Wilson & Tyler, 1980) and the TRACE model (McClelland, 1991; McClelland & Elman, 1986). The main idea of the cohort model (Marslen-Wilson & Tyler, 1980) is that when listeners hear speech, they set up a cohort of possible items the word could be. Then, they remove all candidate words which do not have the same beginning phoneme (e.g., /b/ vs /v/ vs /f/ etc.). This procedure continues until the word is finally recognised (Rost, 2002, p. 22). Their revised model (Marslen-Wilson, 1987, 1990) holds that candidate words vary in their level of activation, that the effects of context on word recognition occur only at a fairly late stage of processing, and that as context influences only the integration stage at which a selected word is integrated into the evolving representation of the sentence, more emphasis is placed on bottom-up processing (McClelland & Elman, 1986). The TRACE model put forward by McClelland and Elman (1986) and McClelland (1991) assumes that both bottom-up and top-down processes interact throughout speech perception, and that three levels of information are used in word recognition, which are phonetic features, phonemes and words. Phonetic features, such as the voicing of a /b/ or /v/, activate all phonemes that contain the same features, which then activate words in the mental lexicon.

These interactive, both bottom-up and top-down, processes are involved in the act of language processing, which eventually leads to comprehension in listening. In the realm of cognitive psychology, listening is defined as an act of information processing (Cutler & Clifton, 1999), the process of selecting, organising, and integrating information (Imhof, 2004), and an intentional and controlled process which requires attentional capacity, expends energy, consumes self-regulatory strength (Schneider & Shiffrin, 1977), and entails information processing across several modalities, such as acoustic and visual signals (Imhof, 2010, p. 98).

Two models of listening have been postulated, one from the behavioural and the other from the cognitive perspective. The behavioural model of listening (e.g.,

Barker, 1971; Wolvin & Coakley, 1996) considers cognitive processes involved in listening along with the interaction of the listener with the speaker (i.e., response), the environment, and affect (Witkin, 1990, p. 19). The cognitive one (e.g., Bostrom, 1990; Taylor, 1964; Wolvin & Coakley, 1993) includes five most often used elements in modelling listening, which are perception, attention, interpretation, remembering, and response (Glenn, 1989), accounting for “what is going on in the listener’s mind at the moment of listening” (Witkin, 1990, p. 19). Nonetheless, it is criticised by Janusik (2004, p. 26) that neither of these models has been scientifically validated. There have been a few models of listening which were empirically investigated (e.g., Bostrom & Bryant, 1980; Bostrom & Waldhart, 1980; Brownell, 1985, 2002; Pecchioni & Halone, 2000), however, each of these has downsides (Janusik, 2010, pp. 207-208).

Bostrom and his colleagues’ cognitive model proposed five steps in listening, which are signal acquisition, selection, literal processing, retention, and comprehension. Although their model was the first one to elucidate psychological underpinnings of listening, it lacked the component of response. Brownell’s model (1985) includes the following six factors: hearing, understanding, remembering, interpreting, evaluating, and responding, so the HURIER model, which is one of the most solid listening models for communication scholars today (Janusik, 2010, p. 208). Brownell (2002) explored what factors would be involved in the listening process with exploratory and confirmatory factor analyses by asking listeners how they perceived listening process worked. Although Brownell’s (1985, 2002) investigations were statistically sound, there are weaknesses with her experimental design (Janusik, 2004, p. 34), and research grounding she based on is limited and obsolete (Janusik, 2010, p. 208). Finally, Pecchioni and Halone (2000) asked their participants to report the nature of the relationship they had with the relational partner who accompanied them to class. The participants were specifically requested to answer what it meant to “really listen” to the other person. Pecchioni and Halone’s (2000) model presents the macro and micro level cognitive, behavioural, and affective processes of relational listening. Relational listening (Halone & Pecchioni,

2001; Pecchioni & Halone, 2000) is the notion that regards listening as an everyday relational activity where the speaker and listener alternate positions and respond to each other (Rhodes, 1993). Although not specified, Janusik (2010, p. 208) criticises that more sophisticated analytical methods should have been used to validate their model. In order to solve these weaknesses, Janusik (2010, p. 209) strongly suggests integration of current attention and memory research, which she refers to working memory (WM) (Baddeley, 1986, 1992, 2000, 2001, 2003; Baddeley & Hitch, 1974), and asserts that advancements in listening research rest on advancements in psychological research.

The theory of WM was developed by Baddeley and Hitch (1974), and furthered by Baddeley (2000, 2002, 2003), which first denoted that the central executive coordinates the two slave systems: phonological loop and visuospatial sketchpad, and later added the notion of the episodic buffer, and it therefore includes episodic long-term memory, visual semantics and language. The concept of WM has become the most influential theoretical perspective in attention and memory research, and it is a central construct in cognitive psychology, more recently, cognitive neuroscience (Miyake & Shah, 1999, pp. 473-474; Shah & Miyake, 1999, p. 1). Janusik (2004, p. 36) argues that the WM theory would provide a more accurate model of the cognitive functions underlying listening, as WM refers to a brain system which provides temporary storage and manipulation of the information necessary for such complex tasks as language comprehension, learning, and reasoning (Baddeley, 1992), and human working memory (i.e., the central executive system) sits in the prefrontal cortex that is involved in concurrent processing of higher cognitive tasks (D'Esposito et al., 1995).

Listening comprehension is a cognitive activity where the listener has to deal with rapid speech stimuli and process linguistic components in real time, in order to understand what the speaker says and intends to convey, and to make an appropriate response. To accomplish this cognitively demanding activity without a hitch, cognitive control (e.g., Baddeley, 1986; Braver et al., 2002; Fan et al., 2002; Miller & Cohen, 2001; Posner & Rothbart, 2007), that involves inhibition and suppression

of current processing focus and shifting of focus (Hugdahl et al., 2009) has to be executed. Baddeley (2003) states that if working memory is a temporary storage system that underpins our capacity for thinking, it is clearly the case that it should have implications for language processing. The role of working memory in ambiguity resolution has been shown (e.g., Daneman & Carpenter, 1983; MacDonald et al., 1992; May et al., 1999) when processing paragraphs which have ambiguous relations between sentences or words, and sentences which have irrelevant endings, so-called garden path sentences (e.g., Frazier & Rayner, 1982).

Daneman and Carpenter (1983) created a paragraph where the preceding context affects interpretation of a word of focus and interpretation of the focus word cannot be complete until coming to the end of the text, so making the paragraph ambiguous, to investigate whether the ambiguity resolution ability would be attributable to the participants' working memory capacity. They used the following text: *There was a strange noise emanating from the dark house. Bob had to venture in to find what was there. He was terrified; rumour had it that the house was haunted. He would feel more secure with a stick to defend himself and so went and looked among his baseball equipment. He found a bat that was very large and brown and was flying back and forth in the gloomy room. Now he didn't need to be afraid any longer.* The preceding context (... *went and looked among his baseball equipment*) would make the participants interpret *bat* as a baseball bat, however, the succeeding context (... *was flying back and forth in the gloomy room*) would unavoidably make the participants interpret it as an animal because a baseball bat does not fly.

Daneman and Carpenter (1983) found that the comprehenders with low working memory capacity were more vulnerable to the textual ambiguities than those with high working memory capacity, implying that low capacity comprehenders are incapable of holding information presented earlier in the text to evaluate the legitimacy of their initial interpretation for their re-interpretation when more contextual information becomes available. Although Daneman and Carpenter's (1983) studies were on ambiguity resolution of visually presented paragraphs, they presumed that what they found in their reading studies could be applicable to

listening studies as the two skills were found to be strongly correlated and shared the common information integration skills (e.g., Daneman & Carpenter, 1980; Jackson & McClelland, 1979).

The role of working memory capacity in ambiguity resolution of auditory sentences has been investigated by Felser et al. (2003). The authors investigated the relationship between relative clause attachment preferences and working memory capacity of two age groups (young (*Mean* age: 6;8) and adult (*Mean* age: 23;6)). Take the following sentence with a relative clause as an example: *Someone shot the servant of the actress who was on the balcony*. There are two noun phrases: *the servant* (NP1) and *the actress* (NP2). The relative clause (RC) is *who was on the balcony*. Hence, RC attachment preferences are given to either NP1 or NP2 when the RC is attached to NP1 (i.e., *the servant who was on the balcony*) or when the RC is attached to NP2 (i.e., *the actress who was on the balcony*). In Felser et al.' (2003) self-paced listening study, the preference for NP2 attachment was observed among young participants with low working memory capacity compared to those with high working memory capacity who showed a preference for NP1 attachment. The preference that is given to the most recently encountered constituent was first called *right association* (Kimball, 1973) and later renamed *late closure* in the garden-path model (Frazier, 1979). Limitations of working memory capacity among both readers and listeners appear to lead them to associate incoming linguistic information with the most recently seen and heard piece of text (Swets et al., 2007). Thus, for successful listening, listeners must often tolerate ambiguity, and wait for later utterances to decide what was intended before (Rost, 2011, p. 36), and more crucially have high working memory capacity. Resolution of these semantic and syntactic ambiguities would only be successful if more context information is available and if the listener has the capacity to store the choice of possible interpretations long enough in working memory to reconsider the validity of the initial interpretation (Imhof, 2010, p. 106).

Findings from cognitive neuropsychological studies provide further suggestions that the clutter of working memory (i.e., the phonological loop and executive

control) caused by neurological damages to the frontal lobe or the dorsal part of the anterior cingulate, may hinder language processing (e.g., Braver et al., 2002; Bush et al., 2000). A growing body of data also supports the view that impairments in cognitive control functions linked to the prefrontal cortex (PFC) underlie higher cognitive impairments including those in attention, working and long-term memory, and language production and comprehension (Carter, 2013, p. 664). For example, symptoms experienced by people suffering from schizophrenia, caused by damages to the frontal lobes and networking areas such as hippocampus and temporal lobes (Kircher & Thienel, 2005), include auditory hallucinations, delusions, disorganised speech production, formal thought disorder, and disruptions in emotion, memory, and executive functions, most of which seem to play significant roles in speech comprehension.

Most everyday communication occurs at a comparatively high utterance length with a moderate linguistic complexity and speech perception in everyday communication is far more complex than usually considered in artificial situations in the laboratory (Kollmeier, 2007). Speech adaptability is demonstrated most explicitly in its resistance to distortion. When conveyed from speaker to listener, speech signals are often modified by background noise and other interfering signals, such as reverberation, as well as by imperfections of the frequency or temporal response of the communication channel (Assmann & Summerfield, 2004, p. 231). Recently, much attention has been directed to the cognitive and neuropsychological mechanism of speech perception in auditorily adverse conditions where the study participants hear several talkers at the same time and also receive non-linguistic stimuli, so as to explore the speech perception mechanism in a real-life condition (e.g., Adank et al., 2012; Assmann & Summerfield, 2004; Cooke, 2006; Cooke et al., 2008; Mattys et al., 2009; Mattys et al., 2005; Romei et al., 2011; Uchanski, 2005; Van Engen, 2010). The nature of processing natural speech stimuli has also been dealt with the role of memory (i.e., working memory) (e.g., Wong et al., 2009) employing the dichotic listening (DL) task (e.g., Alho et al., 2003; Asbjørnsen & Hugdahl, 1995; Bryden et al., 1983; Conway et al., 2001; Engle et al., 1999; Hugdahl, 2003; Hugdahl et al.,

2009; Jäncke & Shah, 2002; Macken et al., 2009; Thomsen et al., 2004), thereby revisiting and re-investigating the mechanism of the cocktail-party effect (Cherry, 1953). Dichotic listening literally means that two different auditory stimuli are presented - one to the left ear and one to the right ear - at the same time (Hugdahl, 2003, p. 446). The effect of attention on dichotic listening performance is to inhibit, or suppress, the processing of the irrelevant signal (*ibid.*, p. 459). Indeed, listeners more often than not hear other people talking in their background and also perceive non-linguistic stimuli such as vehicles, wind, rain, or computers, while controlling the selection of what information to process (relevant) and what to ignore (irrelevant).

The DL task has been applied to investigate the lateralisation of function between the left and right hemispheres (Kimura, 1961a, 1961b). In comparison to an invasive test of language lateralisation (the Wada test; Wada & Rasmussen, 1960), the DL task has been proved to be a non-invasive measure to assess the functional hemispheric lateralisation for language processing (e.g., Bryden, 1963; Hugdahl et al., 1997). Using three (e.g., 482) to five (e.g., 84736) digits in the DL task, Bryden (1963) found that the participants were better able to recognise digits presented to the right ear than the left ear, and suggested that the auditory system is better organised for perceiving verbal materials presented to the right ear. This, in fact, is true (e.g., Hugdahl, 2003; Kimura, 1967; Morton et al., 1998), and has been verified in brain lesion studies (e.g., Pollmann et al., 2002). Hugdahl et al. (1997) sought to verify their DL task as a test to predict hemisphere speech dominance by examining DL performance among patients with a brain disease (symptomatic epilepsy) before and after surgery. Among thirteen patients, ten were judged as left lateralised and three right lateralised for language processing by the Wada test before operation. Performance on the DL test both before and after surgery revealed that all three right lateralised patients were indeed right lateralised (as shown as a left-ear advantage); eight of the ten left lateralised patients left lateralised (as shown as a right-ear advantage), demonstrating clear evidence for a correspondence between an invasive test and the DL test (Hugdahl, 2003, p. 449).

The above-mentioned studies which investigated monolingual listeners indicate that a seemingly easy activity for speakers of one language is, in fact, cognitively wearying. If that is the case, it would be undoubtedly exhausting for speakers of two (or more) languages, i.e., bilinguals, to listen, as they get themselves involved in language activities in two of their languages, one at a time. They also need to switch between their languages whenever necessary, while suppressing an influence from the other, irrelevant one, and ideally maintaining the level of performance in each skill (i.e., reading, listening, writing, and speaking) relatively high, to have a fruitful communication. Research on bilinguals has functioned to a large degree as a testing ground for developed, more general, models of memory or language processing, and furthermore, the bilingual research is now generating models of cognitive functioning which can be extended to more general models of cognition (Keatley, 1992, pp. 40-41). Bilingualism research has suggested that bilingualism influences and enhances executive function, lexical access, executive control, and working memory (Bialystok, 2009), in particular in the inhibition of irrelevant information (Filippi et al., 2012). The next section covers research on bilingualism in more detail, including history of bilingualism research, definitions of bilinguals, and models of bilingual language processing.

2.3 Bilingualism

Research on bilingualism is rooted in the study of brain organisation of the bilingual's two languages, i.e., the study of bilingual aphasics that emerged in the 1860s (Scoresby-Jackson, 1867). Neurologists in those days speculated why patterns of recovery among multilingual patients who suffered from aphasia were inconsistent and why one language recovered earlier and better than the other(s) (Albert & Obler, 1978, p. 2; Fabbro, 2001). Scoresby-Jackson (1867) hypothesised that Broca's area was responsible for the representation of the subject's first language, whereas the portions anterior to Broca's area were responsible for foreign language acquisition. This speculation was, nevertheless, later declined by a study of a polyglot's brain that

Broca's area and the organisations anterior to it were normally extended and demonstrated normal development (Veyrac, 1931). Pitres (1895) argued against the possibility of the differential organisation of the bilingual's two languages, which was verified later by several studies on brain-damaged patients (e.g., Charlton, 1964; L'Hermitte, et al., 1966) that indicated that the majority of aphasic polyglots lose and then recover their languages in proportion to the premorbid degree of fluency in them (Albert & Obler, 1978, p. 2). Results from recent studies on bilingual aphasics have shown that different recovery could be not so much due to the macro-anatomical representation of languages, but due to pathophysiological factors caused by the brain lesion (e.g., Fabbro, 1999).

The early nineteen-fifties observed a first description of bilingual memory organisation which proposed the existence of three kinds of bilingual memory systems (Weinreich, 1953): coexistent bilingualism, merged bilingualism and subordinate bilingualism. The first category claims that the two languages are kept separate; the second that the representations of the two languages are integrated into one system; and the last that L2 is based on the representations of L1. In the following year, Ervin and Osgood (1954) suggested that environments where bilinguals learn their languages affect their memory system: the manner in which a second language is learned governs whether the two languages are stored as a single, compound system or as a dual coordinate system (Albert & Obler, 1978, p. 3). Strong debates over the validity of the compound-coordinate (Ervin & Osgood, 1954) model, which they suggested that if bilinguals learn their languages in different environments, they develop a coordinate memory system where representations of words in different languages are stored separately, came to a temporary end in the 1960s, probably owing to problems in both model and research, also to the general excitement within psychology about models based on information processing frameworks (Keatley, 1992, p. 17). There is still a certain controversy concerning the differentiation of language systems in a bilingual child, and also concerning lateralisation (Herdina & Jessner, 2002, p. 9. See also Vaid & Hall, 1991; Hull & Vaid, 2007). At least at a functional level, language representation in the brain

seems to be different between early- and later-acquired bilinguals, even allowing for individual variation in L2 mastery (Hull & Vaid, 2007). Conducting two meta-analyses of sixty-six behavioural studies, they concluded that early bilinguals (infant onset) are bilaterally organised for language, as among them increased right-hemisphere involvement was observed, and that non-proficient and late onset bilinguals are more left hemisphere dominant in both of their languages (*ibid.*).

In fact, the first studies on bilinguals were carried out by an experimental psychologist, James M. Cattell, in 1887, who explored the effect of interference from one language on the processing of the other (The very first reaction-time study in experimental psychology was conducted by Friedrich Bessel in 1815, where he investigated individual differences in observations of time (i.e., how many seconds have passed), thereby correcting differences among observers (Hergenhahn, 2009, p. 233)). Cattell (1887) compared time spent on naming objects, reading object names and translating concept in the participants' L1 and L2, and found that it took longer to name objects in L2 than in L1, and to translate in either direction than to name objects (Keatley, 1992, p. 28). A shift in methodology in bilingual research was seen in the 1980s, away from recall and recognition studies, to those employing reaction time (RT) as the measure (Keatley, 1992, p. 27). Measuring RTs in the study of cognitive processes can best reveal aspects of mental functioning when experiments are conducted in carefully constructed laboratory situations where conditions can be well controlled (Sternberg, 1998, p. 368). It is also maintained that the measure of RT sheds light on how people process certain parts of language, and it is presumed that the longer time it takes to respond to a sentence, the more processing energy is required (Mackey & Gass, 2005, p. 62). For instance, RT measures can be an integral part of sentence matching experiments because the framework underlying sentence matching is dependent on comparisons of RTs between grammatical matched sentences and ungrammatical matched ones (Mackey & Gass, 2005, p. 63). At the present time, it is rather hard to find a study on bilinguals where RTs are not considered.

Although there were no psychological experiments found between Cattell and 1950s (Keatley, 1992, p. 28), up to this present time, much interest has been drawn from among cognitive psychologists, linguists, neurolinguists, neuropsychologists, and applied linguists, and directed to the cognitive mechanism of bilinguals in language interference (e.g., Preston & Lambert, 1969; Dalrymple-Alford, 1968; Dyer, 1971; Vaid, 1986), language switching (e.g., Chan et al., 1983; Kolers, 1966; Macnamara et al., 1968; Meuter, 1994; Meuter & Allport, 1999), priming effect on lexical decision (e.g., Becker, 1979; de Groot, 1984; Jin & Fischler, 1987), cognate processing (e.g., Beauvillain & Granger, 1987; Caramazza & Brones, 1980), executive control (e.g., Crinion et al., 2006; D'Esposito et al., 1995; Hugdahl et al., 2009; Jackson et al., 2001), and many more. Of most relevance among these fields to the current dissertation are language interference/inhibition, language switching, and executive control in undertaking these feats (all of which are explained in more detail in the following sections), since speech comprehension among bilinguals in one of their languages entails language interference from and effective inhibition of another language, switching from one language to another, and executive control in processing both linguistic and non-linguistic information.

Bilingual advantages and disadvantages in verbal and non-verbal processing

The bilinguals' capacity of managing to produce and comprehend in the two languages has been found to be ascribable to the bilinguals' executive control advantages, which have been investigated and discussed by many cognitive bilingualism researchers such as Bialystok (1988, 1997, 1999, 2001, 2005, 2009), her colleagues (Bialystok et al., 2004; Bialystok & Martin, 2004; Emmorey et al., 2008), and others (e.g., Abutalebi & Green, 2007; Crinion et al., 2006; Filippi et al., 2012; Kovács, 2007; Soveri et al., 2011). Executive control entails cognitive processes responsible for high-level action control, planning, inhibition, coordination, and control of action sequences, which are necessary for maintaining a goal and for fulfilling in the face of distracting stimuli (Kovács, 2007, p. 310), and executive

control is essential to cope with cognitive challenges in everyday life, like in school and at work (Hugdahl et al., 2009).

For instance, comparing fully bilingual children (those fully competent in two languages) with partially bilingual (those in an immersion programme and not fully competent) and monolingual peers, Bialystok (1988) found that the fully bilingual children performed better than the other two groups in metalinguistic tasks, thereby suggesting that the bilinguals have the capacity to resolve linguistic conflicts (both semantic and syntactic) in tasks requiring high levels of control of processing. In a grammaticality judgement task, the fully bilingual children were found to be more successful than partial bilingual and monolingual children in detecting that semantically incorrect sentences were actually grammatically correct (e.g., *Apples grow on noses*). A bilingual advantage shown here in the judgement of grammaticality of that kind of sentences is that bilingual children have the capacity to inhibit the misleading semantic distraction that lures them to (mis)judge that the sentences are *not* correct (Bialystok, 2009).

Yudes, Maces, Morales, and Bajo (2013) compared English monolinguals with bilinguals with different experience in simultaneous interpreting (i.e., nontrained bilinguals, interpreting students and professional interpreters) in their identification of lexical (e.g., KYND (*kind*), OFICE (*office*)), syntactic (e.g., PEOPLE ELDERLY (*elderly people*), SEVERAL WAY (*several ways*)), and semantic (e.g., TELEPHONE SYSTEM (*immune system*)) errors in texts and overall comprehension of the texts. The professional interpreters, i.e., highly advanced bilinguals, were found to be better at detecting syntactic and semantic errors than the other three groups of participants, and to have higher overall comprehension. The authors attribute the better performance among the professional interpreters to not their WM span, but their linguistic skills. As the bilinguals regardless of experience in interpreting were better than the monolinguals in overall comprehension which was accompanied by the identification of errors at the same time, the authors suggest that bilingualism is associated with greater executive control (e.g., conflict resolution) than monolinguals and the bilinguals' experience in detecting and controlling conflicts from another

language may generalise to other type of attentional control tasks including error detection in text processing.

Bilinguals' advantages in executive control processing have been reported not only in the linguistic tasks as shown above but also in non-linguistic tasks. Bialystok (2009) states that if language production (also comprehension) requires the constant involvement of the executive control system to maintain attention to the target language and suppress interference from the other to a minimal degree, it is possible that this experience enhances that system making it more robust for other functions, hence bilingualism should have an advantageous effect on the function of executive control. Many other researchers (e.g., Abutalebi & Green, 2007; Bialystok, 2001; Costa et al., 2008) have shown evidence to support this idea that the constant need for language control increases the ability of the bilinguals to ignore irrelevant information and develop efficient executive control across all domains of perceptual and cognitive processing (Morales et al., 2013). Research on the investigation of bilingual advantages on executive control in comparison with monolingual counterparts routinely uses tasks which are superficially similar but include one condition that additionally requires some aspect of executive control (Bialystok & Barac, 2013, p. 203).

Bialystok and Majumder (1998) compared English monolingual, partially bilingual (Bengali-English) and balanced bilingual (French-English) children on their performance of Block Design, a component of the Wechsler Intelligence Scale for Children-Revised (Wechsler, 1974), to assess the ability to perceive and analyse patterns, the Water Level Task (Piaget & Inhelder, 1956) to evaluate the development of the concept of the horizontal coordinate (i.e., field dependence/independence) in children, and the Noelting Juice Task (Noelting, 1980a, 1980b) to examine children's developing concept of proportion (of orange juice or water). In Block Design (Wechsler, 1974), the children had to combine red-and-white blocks in a designated pattern shown in two-dimensional pictures as accurately and quickly as possible. For efficient duplication, the children had to focus their attention on the separate blocks and reduce the amount of time spent on looking at the pattern as small as possible. In

the Water Level Task (Piaget & Inhelder, 1956), the children were shown pictures of a bottle (half-filled with imaginary water) placed in a particular orientation relative to a horizontal base, and asked to draw the waterline in the bottle and to put an “X” at the position where the water would be. The distracting information in this task was the orientation of the base of the bottle against the horizontal base of the table. The children had to suppress the misleading information of the base of the bottle and focus on the horizontal base of the table, and draw a waterline that would be congruent with the horizontal line. In the Noelting Juice Task (Noelting, 1980a, 1980b), the children were shown two displays where there were a pitcher and a certain number of glasses of water and orange juice each and asked to decide which pitcher would have the strongest taste of orange, or whether they would have the same strength of orange taste. The children had to control their attention not to be drawn to the mere number of glasses of orange juice, but to focus on the ratio of orange juice relative to water. The results indicated support for the bilingual advantage in executive control processing in the nonverbal domain that the balanced bilinguals outperformed the partial bilinguals and monolinguals on the non-linguistic tasks requiring executive control of attention (Bialystok & Majumder, 1998).

Using nine executive function tasks, Carlson and Meltzoff (2008) demonstrated specific aspects of executive control tasks where the bilingual children (kindergarteners) were better than the monolingual children. Their nine tasks were categorised as delay tasks and conflict tasks in a factor analysis. The delay tasks require children to delay a prepotent response and the conflict tasks require children to make a novel response while suppressing a conflicting, prepotent response (Carlson & Moses, 2001). The tasks categorised as delay tasks were Delay of Gratification (Mischel et al., 1989), Statue (Korkman et al., 1998), and Gift Delay (Carlson & Meltzoff, 2008), and those categorised as conflict tasks were C-TONI (Comprehensive Test of Nonverbal Intelligence) (Hammill et al., 1997), ANT (Attentional Network Task) (Rueda et al., 2004), Simon Says (Strommen, 1973), KRISP (Kansas Reflection/Impulsivity Scale) (Wright, 1972), DCCS (Dimensional

Change Card Sort) (Zelazo et al., 1996), and Visually cued recall (Zelazo et al., 2002).

Carlson and Meltzoff (2008) found that although performance did not differ in the delay tasks between the three groups (i.e., bilingual children from birth, children in an immersion programme, and English monolingual children), the bilingual children outperformed the other two groups particularly on conflict tasks, the tasks that involved conflict for competing items that had to be effectively resolved for a correct response. Bilingual advantage on conflict resolution on executive control tasks other than these shown above has been reported by Craik and Bialystok (2006) and Emmorey et al. (2008) among others.

Craik and Bialystok (2006) gave a 'cooking breakfast' task to young and older adults, half of which were monolinguals and the other half were bilinguals in each group, and investigated the relationship between their performance in the cooking breakfast task and their executive control. The cooking breakfast task was a virtual cooking task administered on a touch screen monitor. The task was to prepare a virtual breakfast consisting of five foods and to set a table while the foods were cooking. As there was no clue for when the food was ready, the participants had to monitor the time to stop each food at the proper time and estimate when to start cooking each food to maximise the foods' simultaneous completion. The results showed that there was no difference in the performance between the monolingual and bilingual participants on the main breakfast cooking task, however, the bilinguals were found to spend a smaller portion of the overall task time in table setting, suggesting that the bilingual participants, especially among the older bilinguals, made more effective use of their time in the task, and were more efficient in switching to food-related operations when it was appropriate.

Emmorey, Luk, Pyres and Bialystok (2008) extended the view of bilingual advantage in executive control to the bilingual modality and investigated whether the cognitive enhancement would spring from a general effect of bilingualism or from a modality constraint that forces language selection in unimodal bilinguals (those who know two spoken languages), bimodal bilinguals (those who know both a spoken

language and a signed language) and monolinguals on a set of flanker tasks. There were three types of blocked trials in the flanker tasks. In each condition, the target was always a red chevron pointing to either left ($>$) or right ($<$), placed either at the centre among the other four chevrons or next to the centre. The participants were instructed to indicate whether the target red chevron pointed to the left or right. In control blocks, a single red chevron, pointing to either left or right, was shown and response times in these blocks were used as baseline response times. In go/no-go blocks, there were go trials and no-go trials. In the go trials, a red chevron was placed at the centre and was surrounded by red diamonds, two on each side ($\diamond \diamond < \diamond \diamond$). In the no-go trials, the target red chevron was at the centre, but surrounded by four red Xs ($\times \times > \times \times$). This go/no-go condition required the participants to monitor and prevent from responding to the no-go trials. There were congruent (distractors pointed in the same direction as the target red chevron) and incongruent (distractors pointed in the opposite direction) trials in conflict blocks. In these blocks, unlike the go/no-go blocks, the target red chevron could be at the centre or one chevron left or right from the centre (congruent: $< < < \leq <$, incongruent: $< \geq < < <$, targets underlined). The conflict condition required the participants to maintain their focus only on the direction of the target chevron and suppress the flanking distractors effectively.

Here again, Emmorey et al. (2008) demonstrated that the unimodal bilingual participants performed significantly faster than the other two groups in all experimental conditions, although the accuracy in their responses did not differ between groups. The authors suggest that the executive control advantage found among the unimodal bilinguals who use two spoken languages is owing to their constant conflict with more challenging production demands than bimodal bilinguals since their languages employ the same articulation system and they must strongly inhibit their other language in order not to cause confusions for their interlocutor. Bimodal bilinguals, on the other hand, seldom switch between languages, but prefer to code-blend, that is, simultaneously producing signs and words (Emmorey et al., 2008). Bimodal bilinguals are often found to be producing signs and speaking to

nonsigners (Casey & Emmorey, 2009) and this does not seem to be as disruptive as controlling and producing one of the two languages among unimodal bilinguals. Hence, extensive practice with more difficult selection and control processes may improve response selection and attentional control in a way that generalises from language to cognition for unimodal bilinguals (Emmorey et al., 2008).

In a recent study, Morales, Gómez-Ariza, and Bajo (2013) compared monolinguals and highly proficient bilinguals in their performance on an AX version of the Continuous Performance Test (AX-CPT) (CPT; Rosvold et al., 1956), a version of the CPT used by Ophir et al. (2009), to investigate the dynamics of proactive and reactive control to overcome interference from distracting information (e.g., Bialystok et al., 2012; Braver, 2012; Costa et al., 2009). In this task, participants are shown cue-probe pairs and are required to respond “yes” to a target X-probe when it is preceded by an A-cue and to respond “no” to any other cue-target combinations (e.g., AY). Proactive control is subject to contextual cues which prompt goal activation and maintenance in advance of the time when those goals are needed, hence when expectancy is high proactive control is engaged (e.g., Braver, 2012; Miller & Cohen, 2001). On the contrary, reactive control is stimulus-driven, that is it is not subject to contextual cues, and relies on the detection and resolution of interference after its onset (e.g., Braver, 2012; Jacoby et al., 1999). A stop-signal task (Logan & Cowan, 1984) was also employed to examine the relative involvement of proactive control and reactive inhibitory control required in the AX-CPT. In the stop-signal task, participants are asked to respond to the target stimuli, but they have to hold their response whenever they are shown a stop signal. Morales et al. (2013) sought to demonstrate whether bilinguals would perform better than monolinguals when it is necessary to adjust proactive and reactive control and examine the relationship between performance in the AX-CPT and the stop-signal reaction time (SSRT), a measure of inhibitory efficiency (Verbruggen & Logan, 2008).

Results showed better inhibitory control among the bilinguals than monolinguals where higher requirement of proactive-reactive control adjustment was required (i.e., AY condition), although these two groups of participants were matched for

intelligence and age. A significant correlation was found only among the bilinguals between the SSRT and the proportion of errors in the AY condition, indicating that bilinguals relied more on inhibition than the contextual cues to produce fewer errors in this condition. Morales et al. (2013) present a bilingual advantage when greater control is required and a differential role for inhibitory processes in bilinguals relative to monolinguals. Their findings show that it is necessary to focus on the coordination of more than one component of control (i.e., both proactive and reactive control) to fully account for the observed pattern (Bobb et al., 2013).

Lastly, the advantageous impact of bilingualism across the lifespan is presented. Ageing usually affects several aspects of cognition such as memory, executive function, language and structural changes at the cerebrum level, emerging as cognitive challenges such as dementia. Bialystok, Craik, and Freedman (2007) revealed a positive aspect of bilingualism that can slow down the onset of cognitive decline among the elderly population. The authors collected 91 monolingual and 93 bilingual elderly people who had been diagnosed with dementia and compared the age of onset of the symptoms, performance on a cognitive measure (the Mini-Mental State Examination), and language, education, and job histories. Although the monolingual and bilingual participants performed equally on the cognitive task and their job statuses were comparable, the age of dementia onset for the bilinguals was, strikingly, four years later than it was for the monolinguals. The authors (Craik et al., 2010) replicated their study with roughly two hundred participants, half of which were bilingual, who were equivalent in cognitive level, and found that the bilinguals were faced with symptoms of dementia more than five years later than their monolingual counterparts. No other pharmacologic interventions have been found to have comparable effects. Bilingualism, that is extensive use of two languages while switching between them when necessary, that requires resolution of linguistic and cognitive conflicts, can postpone the onset of symptoms (Craik et al., 2010).

Although findings described above might show only bilingual advantages, bilinguals have been found to be disadvantaged in language proficiency and lexical fluency of the second language compared to monolinguals who speak that language.

Bialystok, Luk, Peets, and Yang (2010) compared the size of receptive vocabulary between monolinguals and bilinguals, and found a larger size of vocabulary among monolinguals across the ages of 3 and 10. Although the overall vocabulary size among monolinguals was reliably larger than bilinguals, the authors showed that there was no difference in scores on words associated with schooling since all the child participants were educated in English and the difference in the size of vocabulary of home and social contexts was owing to the fact that English was found not to be used in bilingual homes as extensively as those of monolinguals. Hence, the smaller vocabulary for bilingual children in each language is not an overall disadvantage but rather an empirical description that needs to be taken into account in research designs, especially tasks that involve verbal vocabulary or lexical processing (Bialystok & Barac, 2013, p. 195).

Rodriguez-Fornells et al. (2005) found that the bilingual participants were slower in their picture-naming task than the monolingual participants (also found by Costa, 2005). Bilingual deficits have been also reported in verbal fluency (e.g., Portocarrero et al., 2007), experiencing more interference in lexical decision (e.g., Ransdell & Fischler, 1987), and where more relevant, poorer word identification and comprehension in noise (García Lecumberri & Cooke, 2006; MacKay et al., 2001; Mayo et al., 1997; Rogers et al., 2006). Bialystok (2009) presented three possible reasons for why bilinguals experience deficits in lexical access. One of them is given by Michael and Gollan (2005) that bilinguals' less frequent use of their two languages has created weaker links among the relevant networks necessary for quick and smooth speech production. Second, outcomes of vocabulary acquisition in L2 depend on the age of L2 acquisition (Hernandez & Li, 2007), hence, the earlier bilinguals start learning an L2, the better and more efficient their lexical access might be. Third, the reduced efficiency in lexical access might be due to the conflict bilinguals need to resolve that comes from the competition from the corresponding item in the other language (Green, 1998; Kroll et al., 2008).

Bilingual deficits that are relevant to the current research are also presented. Compared to monolinguals, bilinguals have been found to be more influenced by the

noise in the real-life listening environment (Black & Hast, 1962; Meador et al., 2000). Early bilingualism does not seem to necessarily help bilinguals listen and comprehend as well as their monolingual peers (e.g., Mayo et al., 1997). Some attribute these deficits to the bilingual's need to search for an appropriate response (e.g., a word) in the bilinguals' two mental lexicons (Hapsburg & Pena, 2002; Weiss & Dempsey, 2008). Errors made in an L2 listening task conducted in noise may stem from the influence from the phonological system in L1 (García Lecumberri & Cooke, 2006; MacKay et al., 2001), and the degree of influence from L1 is related to the degree of activation of L1 (MacKay et al., 2001; Meador et al., 2000). It has been also found that the accuracy of a listening task in noise depends on the quality and quantity of L2 input received in the bilingual's daily life (Bradlow & Bent, 2002; Quené & van Delft, 2010). Surprisingly, given that bilinguals must disentangle auditory messages, there is a dearth of enquiries examining a bilingual functioning advantage in the auditory modality (Filippi et al., 2012).

Integration of psycholinguistics and working memory with bilingualism

Psycholinguistics, one of the research disciplines that has been integrated into the current research, incorporates psychology and linguistics by examining the mental processes and types of knowledge involved in understanding and producing language (de Groot, 2011, p. 2). Psycholinguistic approaches to bilingualism have offered deeper insights, often laboratory based, but using carefully designed experiments or standard assessments, into how multiple languages are simultaneously acquired and represented by the bilingual individual (Wei, 2013, p. 41). Relatively many of both the comprehension and the production studies on bilinguals that have been performed have investigated the processing of words instead of larger linguistic units such as complete sentences or texts (de Groot, 2011, p. 4). Furthermore, there have not been a sufficient number of examinations on bilinguals' cognitive and language control in the auditory domain, possibly due to the difficulty when conducting perception studies on bilinguals (Grosjean, 2008, pp. 77-78) that is concerned with

how to prevent the bilinguals from activating, to some extent at least, the other language, i.e., monolingual mode, since perception studies are usually conducted in a single language, unless the task requires both languages (e.g., the bilingual Stroop test, bilingual word priming, bilingual association production, bilingual category matching, word translation, etc.) (Grosjean, 2008, p. 58).

In the monolingual mode, bilinguals interact with monolinguals with whom they cannot use their other language (Grosjean, 2008, p. 40). In this mode, one of their languages is most activated, but the other is less activated. It is not as easy as one wishes it to be to put a bilingual in a monolingual mode in experimental perception tasks (Grosjean, 2013, p. 17) because there are several bottom-up and top-down factors which can be involved in causing the mode to move towards the bilingual end of the continuum in perception experiments (Grosjean, 2008, p. 78). In the bilingual mode, bilinguals interact with other bilinguals with whom they feel comfortable mixing languages. In this case, both of their languages are active with one of them not in use at the moment less active than the other (Grosjean, 2008, p. 41). The bottom-up factors include code-switches/borrowings, cross-language homographs, shared word onsets in phonetically similar languages, high density of cognates, and high density of interlingual homographs (in reading). The top-down factors include knowing that the experiment is related to bilingualism, bilingual university environment, laboratory doing bilingual research, bilingual experimenter, bilingual task, and low proficiency in language of study, so relying on the knowledge of the other language.

Notwithstanding, what would be necessary and intriguing to do is not to be troubled over whether bilinguals completely switch off the unattended language, as it is impossible to switch off the language not in use (Kroll et al., 2012), but to investigate how they comprehend incoming speech in one of their languages while overcoming other auditory, interfering information, which could be either their L1 or L2. One recent ERP study (Thierry & Wu, 2007) has demonstrated that higher-intermediate (6-6.5 in IELTS) bilingual speakers (Chinese-English) unconsciously gain access to their first language to comprehend what is presented both visually and

auditorily (words) in their second language. Hence, while receiving L2 stimuli, they do not seem to switch off their L1 completely (plausibly impossible), but use the network between their L2 and L1 to access the meaning of L2 words which they memorised in their L1. Maintenance of attention to L2 words while obtaining meanings in L1 must require cognitive control to some degree so that bilinguals can make quick and accurate responses.

Working memory, which is the third research discipline considered in the present research, has also demonstrated its crucial role in the bilingualism literature, in that executive functions of working memory, inhibition, shifting, and updating, underpin efficient language switching, lexical selection, parsing complex syntactic structures (e.g., Soveri et al., 2011). Engle and Kane (2004) argue that working memory capacity (WMC) is most important when goal-related information must be actively maintained to guide response selection, especially if viable but contextually inappropriate response alternatives are also available. Conway and Engle (1994) emphasise that WMC is responsible for maintaining activation to relevant information and suppressing distracting information. Speech perception in bilinguals would find the relevant and goal-oriented information as the language in use and the potentially inappropriate and distracting information as the other language not in use. Speech perception, i.e., listening, requires a functioning self-regulatory system with comprehensive attention and working memory capacity (Janusik, 2004), because the relevant stimuli are temporally distributed, which means that they are transient and not available for further reference (Imhof, 2010, p. 98). Probing the role of WMC, that is how it is performed, would delve further into the cognitive mechanism of speech perception among bilinguals.

Observations of the history of studies on bilinguals, the significant roles psycholinguistics has played in bilingualism, and the scarcity of research on cognitive processes of linguistic components which are larger than words, particularly at the auditory level, would convince one to undertake investigations on cognitive processes involved in speech perception, which would add a new chapter to the history of psycholinguistic studies on bilingualism.

On these accounts, this dissertation endeavours to demonstrate the cognitive mechanism of bilingual speech comprehension from viewpoints of bilingualism, psycholinguistics and WMC, which would ultimately lead to an additional notion to the general model of cognition in language processing.

2.3.1 *Who are bilinguals?*

Defining who is classified as a bilingual is a more complicated task than it appears. Views on defining a bilingual range from a rather extreme one by Bloomfield (1933) that a bilingual has full fluency in two languages to a more pragmatic one by Grosjean (1989) that a bilingual is someone who can function in each language according to needs at hand (Bialystok, 2001, p. 4). Grosjean (2008, p. 10) later defined bilinguals as those who use two or more languages (or dialects) in their everyday lives. Wei (2000, pp. 4-5) has shown a list of thirty-seven varieties of bilinguals depending on the achieved competence in the second language (e.g., balanced bilingual, functional bilingual, minimal bilingual), and on when (e.g., early and late bilinguals) and how the second language is learned (compound bilingual, coordinate bilingual, successive bilingual) and used (e.g., productive bilingual, receptive bilingual).

Brain imaging studies on bilinguals have provided some counterintuitive results that what determines the brain organisation of semantic processing - language comprehension at least - of the two languages is not the age of acquisition (i.e., how early or late it is learned), but is rather the ultimately attained level of L2 proficiency (e.g., Abutalebi, 2008; Abutalebi et al., 2005; Perani et al., 1998). The age of acquisition has been found to selectively influence bilingual brain organisation of syntactic processing (e.g., Wartenburger et al., 2003; Weber-Fox & Neville, 1996). There seem to be other behavioural factors which can alter the way the two languages are processed, such as, for example, the amount of daily exposure to the L2, causing differential brain activation (e.g., Perani & Abutalebi, 2005; Perani et al., 2003; Vingerhoets et al., 2003), and the way the L2 was learned, either informally (in

a more natural language acquisition environment, e.g., through relaxed interactions), leading to greater right hemisphere involvement or formally (in a more traditional language learning environment, e.g., classroom), leading to greater left hemisphere involvement (Paradis, 2003; Vaid, 1983). Therefore, how bilingual a bilingual person is can not be determined by assessing only one aspect of linguistic processing (i.e., semantic or syntactic), or by language acquisition (learning) and language use history, but needs considerations of all of those that can influence the bilingual's language behaviour and corresponding cognitive change.

A measure that has been used to enquire the participants' profile in terms of bilingual language experience is the language history questionnaire (e.g., Kilborn, 1987; Li et al., 2006; Liu et al., 1992). In the questionnaire, bilingual participants answer questions about their language learning history (e.g., age of L2 acquisition, exposure to L2, context in which they learned L2), amount of exposure to and use in L1/L2 with whom and where, language behaviour (e.g., calculating, dreaming, and expressing anger) and preference (e.g., preferred language to use at home, work, or in general), and history of taking standardised English proficiency tests (e.g., TOEFL, IELTS), etc., which most researchers consider important to be included in a language history questionnaire. Their construct validity and content validity have been validated empirically by the authors with the split-half coefficient at .85 (e.g., Li, et al., 2006; Sepanski, 2005).

Research on bilingualism has tackled extensively bilinguals who speak two (or more) languages which share the same script (e.g., Dutch-English bilinguals) and investigated cognitive and language control and competition largely in production tasks such as the picture-naming task (e.g., Rodriguez-Fornells et al., 2005; Verhoeft et al., 2009). The current research seeks to contribute to the development of bilingualism research on speech perception/comprehension and overcome the apparent lack of research on cognitive and language control in speech perception/comprehension among bilinguals (e.g., Filippi et al., 2012), especially, who use different scripts and language systems such as Japanese-English bilinguals.

Managing to be engaged in a communication in both of these linguistically different languages while switching between them when necessary, and maintaining a certain level of performance in the four skills must be a strenuous task. In fact, listening in L2 requires conscious attention to the language and is often not automatically processed due to the speed of speech and the inability of working memory to process all the information within the time limitations, and barriers to comprehension and additional processes L2 listeners have to perform make listening in L2 an onerous task (Flowerdew & Miller, 2005, p. 27). Furthermore, Weber and Cutler (2004) pointed out that non-native listeners not only experience competition from lexical candidates in the inactive language (their L1), but also experience competition from candidates in the language in use at the moment, which native listeners would not experience under normal listening conditions. The bilingual's communicative competence cannot be evaluated correctly through only one language, instead it must be studied through the bilingual's total language repertoire as it is used in his or her everyday life (Grosjean, 2008, p. 14).

Li and Green (2007) have called upon that more research be conducted on bilinguals who speak Asian languages as these languages have specific linguistic properties (e.g., non-alphabetic scripts/writing systems, lexical tones, flexible grammatical and syntactic structures, and unique lexical compounding characteristics) not available in commonly examined languages (e.g., Spanish, Dutch, German, Italian, etc.). Li and Green (2007) argue that these properties specific to these Asian languages have not been extensively investigated in the bilingual context.

For these reasons, it was considered intriguing, rather empirically meaningful to conduct research on Japanese-English bilinguals and investigate the cognitive mechanism of speech comprehension in both of their languages. Although 47% of its lexicon is made up of Chinese loan words and its orthographic systems derive from Chinese characters, Japanese is not related to Chinese (Loveday, 1986). Japanese is not written in pure *kana*, but it employs a mix of alphabetic, syllabic, and logographic writing devices (Knight & Yamada, 1999). Japanese is not only different

orthographically, but also syntactically (Greenberg, 1963), phonologically (Fox, 2000; Shibatani, 1990), and in focus in an utterance (Hinds, 1986; Monane & Rogers, 1977). Findings from the current research would lead to a new exploration of the bilingual's cognitive mechanism underlying the governance of language control and cognitive control in speech comprehension. A contrastive view of the Japanese language to the English language is more precisely, but briefly presented below.

2.3.2 *Language use among bilinguals*

Bilinguals use their two languages in several different situations and with other people who might or might not share their languages. It is commonly known from psycholinguistic studies that exercise, usage, and experience may enhance performances of production and comprehension in L2 (Green, 1998). Despite that, for example, none of the imaging studies have taken into consideration the role of environmental exposure on cerebral language representation, or its relationship to the first and second language in (early) bilinguals (Perani et al., 2003). The authors demonstrate that in a production task, both age of acquisition and language exposure affect the pattern of brain activation in bilinguals. The same facilitatory effect of language experience on speech perception has been also reported that language experience facilitates perception of English phonological contrasts (between /ɪ/ and /ɜ/, and between /d/ and /ð/) and this facilitation occurs later in development when English and another language (e.g., French) are acquired simultaneously (Shafer et al., 2011; Sundara et al., 2006). It is related to the point mentioned earlier that researchers looking into speech perception have directed their attention to investigations in more pragmatic situations.

The bilingual's language contacts may be with the languages used in the home, in the community, in the school, in the mass media of communication, and in her correspondence (Mackey, 2000, p. 25). In the home, some families hire a domestic worker or governess who speaks another language and encourage them to speak that language to the children. In families where one of the parents speaks a second

language, this language may be used as one of two home languages with their children (*ibid.*). Children in families under such situations acquire two (or more) languages without as much effort as required when learning a second language at school.

Languages spoken in the community are those spoken in the neighbourhood, ethnic group, church group, occupation group, and recreation group (Mackey, 2000, p. 27). For example, a child is surrounded by the language of the neighbourhood into which he is born, and this often takes the place of the home as the most important influence on his speech (*ibid.*). Inevitably, bilingual children live different lives than their friends and neighbours who may be socially, economically, and politically similar but speak only one language (Bialystok, 2001, p. 9).

At school, bilingual children are taught a language as a subject or a language is used as a medium of instruction. Some of them go to school where subjects are taught in another language (*single medium*) or in both of their languages (*dual media*) (Mackey, 2000, pp. 27-29). Some others learn and get exposed to a second language with a private tutor (private tuition) anticipating more extensive contact with the language.

Mass media are what is surrounding bilingual children and giving them as much exposure as possible in reading (e.g., newspapers, magazines, books), and listening (e.g., radio, TV programmes, movies). Mackey (2000, p. 29) includes correspondence as the last category of language contact among bilinguals.

As seen above, bilinguals usually acquire and use their languages for different purposes, in different domains of life, with different people. Different aspects of life often require different languages. This is the Complementarity Principle suggested by Grosjean (1997). In a family, children speak with each other in one or two of their languages, which they might have learned at school. When they talk with their mother, they use their third language shared by their mother as she does not speak their two languages. The same language shared by all of them can be used at a local place (e.g., church). As such, context can shape an individual's proficiency levels in the two languages seen in the above example in each of the skill domains (e.g., with

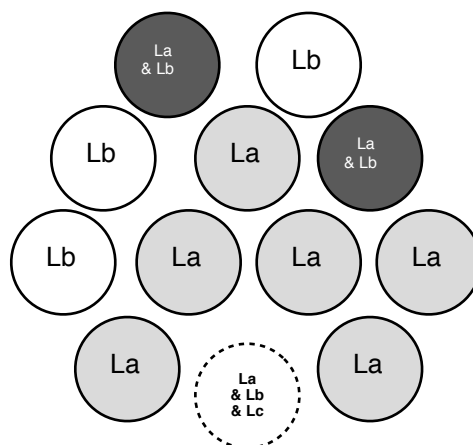


Figure 2.1. The domains covered by a bilingual's three languages (La, Lb, and Lc). A reproduction based on Grosjean, 2013, p. 11)

parents, siblings, relatives, friends, at work, for sport, when shopping, when writing an essay, etc.) (Butler, 2013, p. 115). The pattern of bilingual's language use is depicted by Grosjean (2013, p. 11) that is shown in Figure 2.1.

The domains are represented by circles in which one language (La (language a) or Lb (language b) only) or two languages (La & Lb), or even, in Grosjean's case, three languages (La, Lb, and Lc (language c)) are used independently or interchangeably. In this example, the bilingual speaker deals with six domains in La only, three domains with Lb, two domains with La and Lb, and one domain with the three languages. It is rare and even illogical to find bilinguals who deal with all their domains with all their languages. Bilinguals are also rarely proficient in all domains in both of their languages (Butler, 2013, p. 115), that is the more domains one of their languages is used for, the higher the frequency of use and therefore, usually, the greater the fluency (i.e., proficiency) (Grosjean, 2013, p. 12).

According to Figure 2.1, the dominant language of the bilingual is La, which is used in six domains out of ten. Dominant language is the preferred and best spoken language and language dominance varies according to the context where those languages are used and even across time (Ardila, 2007, p. 10). Care has to be taken, because the fact is that the non-dominant language can be the sole language for some domains such as counting, praying, and telling phone numbers, and the dominant

language for particular domains (Grosjean, 2013, p. 13). Grosjean refers to Cooper's (1971) study where he found that Spanish-English bilingual participants sometimes showed balanced word naming scores depending on the domain referred to, whereas they showed in other domains dominance in one language. Hence, it might be safer to mention that dominant language is not necessarily the most used language in any domain, could be the most proficient language as it has become one's proficient language after extensive use, but the language used most often specifically in some domains. It is formed through the bilingual's everyday experiences, for example, with their bilingual family, in their neighbourhood where people speak different languages, and at school where the medium of instructions is in one of their languages.

Memories of events, whether particular or not, seem to be better recalled in the language in which they happened, that is called language-dependent recall (Marian & Neisser, 2000). Their study participants (Russian-English bilinguals) were asked to recall life experiences after hearing each prompt words such as summer, neighbours, birthday, cat, doctor, getting lost, frightened, and bride. They were interviewed in either Russian or English. As a result, the participants recalled more experiences they had in Russian when interviewed in Russian and more experiences in English when interviewed in English. In general, information that is acquired in a certain linguistic ambiance is likely to become more accessible when recall takes place in that same ambiance (*ibid.*). Bilinguals get involved in life events in different domains in, for example, their dominant language, that leads to more memory encoding and recalling experiences in that language.

Matsumoto and Stanny (2006) found the phenomenon of language-independent memory among their Japanese-English bilinguals. The participants were invited to an interview where they were presented visually on a card and auditorily (to avoid any confusion that could be caused by homophones) with twenty Japanese and twenty English words, from each of which they were asked to describe the first personal memory associated with the word. The participants were also asked to tell the experimenter the language of their first thoughts triggered by the cue word and the

language of encoding immediately following retrieval of each memory. Monolingual US students were also included, but they were shown cue words only in English.

As a result, the bilingual participants were found to recall significantly more and earlier memories when they saw Japanese words than when they saw English cue words, and when the cue language matched either the language of memory encoding or the language of first thought. Second language proficiency may influence access to autobiographical memory, that is, the more proficient a bilingual becomes in L2, the more comparable the numbers of memories in her two languages becomes. Although the ages of the earliest memory did not differ for US and Japanese participants, the average age of cued memories reported by US monolinguals was significantly earlier (4.7 years earlier on average) than that reported by Japanese bilinguals.

The authors conclude that (highly proficient) bilinguals have easier access to their memories (in both languages), especially memories from childhood, on condition that there is a match between language of encoding and language of retrieval (Matsumoto & Stanny, 2006). It has been also revealed elsewhere that memories that share a linguistic encoding context with the retrieval context are more numerous, more detailed, and more emotional than memories from an incongruent linguistic context of encoding (Bugelski, 1977; Larsen et al., 2002; Schrauf, 2003). This pattern suggests that episodic memories retain *language-dependent* information that affects retrieval, whereas access to semantic memory seems *language-independent* (Bartolotti & Marian, 2012, p. 15).

How and where bilingual children use their two languages has been found to influence the size of their vocabulary in different domains (e.g., homes and schools) (Bialystok et al., 2010). As mentioned earlier, the longer they spend on using their L2 at home, the larger the size of L2 vocabulary, that is related to home issues, becomes. Apparently, bilinguals' language use and L2 learning environment seem to not only change the amount of lexical knowledge in L2, but also alter the way they use it. Malt and Sloman (2003) collected bilinguals (though specified as non-native speakers of English by the authors), who were varied in their L1s, L2 proficiency,

years of immersion in an English-speaking environment, and years of formal instruction in English, and gave them an object naming task, in which objects to be named were storage containers such as jars, bottles, and housewares such as bowls and dishes. Whether the bilinguals' responses were like those of native speakers was analysed by comparing responses in the object naming task between these two groups of speakers. Familiarity rating of objects that are not completely the same ones in the experiment, but similar to them, showed that the bilingual participants also showed different familiarity ratings of the bottles and dishes, but these ratings were comparable with those of native speakers and dishes.

Results showed that the amount of immersion in an L2 environment, other than L2 proficiency acquired through formal instruction and age of L2 acquisition, predicts the mastery of native-like naming patterns. Discrepancies found between native speakers and bilinguals with high proficiency and more than ten years' immersion experience could be due to the ways in which the differences between the learners' native naming patterns and the to-be-learned patterns affect their performance. First, bilinguals acquiring L2 at an earlier stage may import the pattern of links from objects to words that their native language uses, thereby causing interference from the imported pattern in the process of acquiring the new pattern. Second, mature L2 learners' tendency to use contextual information in communication may lead them to ignore details of form and prevent them from noting discrepancies from their own implicit version of the same material. Lastly, L2 learners' continuous use of their native language with their family and friends, and interactions with other non-native L2 speakers, may leave their non-native patterns intact. Although it seems necessary not to use one's native language in order to acquire a fully native-like command of L2, they have at least shown that the way bilinguals acquire and use their L2 may alter the bilinguals' memory representations of L2 and can lead to native-like usage of referents.

Considerations of the ways in which bilinguals use their languages in their daily life, and their effects on cognitive development and memory construction, would

motivate investigations on more practical aspects of the cognitive mechanism of speech comprehension among bilinguals under the real-life situation.

2.3.3 Psycholinguistic approaches to bilingual speech comprehension

This section focuses on presenting previous studies which have investigated bilinguals on their speech (listening) comprehension. First and foremost, a notion of speech comprehension in psycholinguistic studies of bilingualism has to be presented and made recognised in order to clarify what it means by “comprehension” in this dissertation.

Much research on language comprehension has focused on the processes involved in understanding words in isolated context and separate sentences. Nonetheless, comprehenders are generally presented with a larger linguistic entity, that is connected discourse (written text or speech at least several sentences in length) (e.g., Ingvalson et al., 2014). Bilingual listeners are no exception to this common circumstance. In real-world interactions, listeners almost never hear phonemes in isolation (Ingvalson et al., 2014), but larger linguistic units such as words, sentences and passages. Hence, comprehension is an act of understanding a large linguistic unit, i.e., discourse, following and integrating the processing of smaller linguistic units, i.e., phonemes, semantics, syntax, and pragmatics, leading to the understanding of the intended meaning.

Psycholinguistic studies on bilingual speech comprehension have used tasks such as the word recognition task, which requires participants to recognise whether what they heard was, for example, *pan* or *pen* (perception of contrast between /æ/ and /ɛ/) (Schouten, 1975). In the bilingual word recognition task, these bilingual participants (e.g., Dutch-English bilinguals) have been found to be more affected by their L1, that is, cross-linguistic similarity in words that sound very similar across languages (e.g., desk (/desk/ [English] and deskill (/dɛksəl/ [Dutch])), because their phonological representation of L2 words may be less specific or represented in terms of phonemes that are more like those in their L1 (Pallier et al., 2001). Thus, bilingual listeners are

slower in their identification of L2 spoken words, less accurate and less confident in their task performance than monolingual counterparts (e.g., Blumenfeld & Marian, 2007; Scarborough et al., 1984; Schulpen et al., 2003). Bilingual listeners cannot deactivate their L1 lexicon that is irrelevant in a monolingual L2 situation (Weber, 2001). As bilinguals have lexical knowledges of two languages, despite knowing fewer words in their second language, they have to identify words from among a larger pool of concurrently activated candidates than monolinguals, that is, in bilinguals, more lexical candidates compete for recognition than in monolinguals (FitzPatrick & Indefrey, 2010).

Critically and counterintuitively, even proficient bilinguals seem unable to switch off the language not in use when they listen, read, or speak one language alone (e.g. Dijkstra, 2005; Kroll & Dussias, 2013; Marian & Spivey, 2003a, 2003b), thereby creating cross-language competition (Kroll et al., 2012), which is also known as bilingual parallel activation (e.g., Kroll et al., 2008; Marian & Spivey, 2003a, 2003b), cross-language lexical competition (e.g., Dijkstra et al., 1998; Kroll & Sunderman, 2003; Lagrou et al., 2011), and language non-selective lexical access (e.g., de Groot et al., 2000; Duyck et al., 2007). In studies of online comprehension (e.g., Dijkstra, 2005; Kroll & Dussias, 2004; Schwartz & Kroll, 2006), this interruption from the unattended language is most often investigated at the *word* level and rests on evidence that lexical representations in the irrelevant language sharing features with spoken or written words encountered in the currently used language are activated at an unconscious level (Chambers & Cooke, 2009). In the light of the situation, Spivey and Marian (1999), Marian and Spivey (2003a, 2003b), Chambers and Cooke (2009), FitzPatrick and Indefrey (2010), Hahne and Friederici (2001), and Hahn (2001) investigated the cognitive processing of spoken stimuli at the *sentence* level among bilinguals. The former researchers (Chambers & Cooke, 2009; Marian & Spivey, 2003a, 2003b; Spivey & Marian, 1999) employed the visual-world paradigm with an eye-tracker that is useful for detecting effects of sentence context on lexical competition in monolingual contexts, that is, when bilinguals are listening to and comprehending one of their languages (e.g., Dahan et

al., 2002; Magnuson et al., 2008). To follow up these behavioural studies, the latter researchers (FitzPatrick & Indefrey, 2010; Hahn, 2001; Hahne & Friederici, 2001) made use of the brain imaging apparatus called the event-related potentials (ERPs) which has an advantage of providing a direct measure of real time brain activity at the millisecond level in, e.g., reading for comprehension, and has the potential to highlight the temporal unfolding of neural events associated with different subprocesses of language perception or production (Moreno et al., 2008).

The eye-tracking method provides an online index of spoken language comprehension by observing what the listener looks at in the visual field while perceiving speech (Tanenhaus et al., 1995). It has been found that a written word initially activates a set of orthographic word representations in the mental lexicon that have common orthographical features with the target word (e.g., when primed with a word *sonno* (Italian), other orthographically similar words such as *nonno*, *campo*, *ponno*, and *crona* are also activated, Colombo, 1986), whereas a spoken word initially activates a set of phonologically similar word candidates in memory (e.g., Grainger & Dijkstra, 1992; Tanenhaus et al., 1980). Previous research has found that monolingual listeners are drawn their visual attention to an item which has a phonological similarity at an earlier stage to the spoken target word, e.g., they briefly look at a picture of a *candle* when required to choose the *candy* (e.g., Tanenhaus et al., 1995; Spivey-Knowlton et al., 1998).

Marian and Spivey (Marian & Spivey, 2003a, 2003b; Spivey & Marian, 1999) investigated lexical competition in processing spoken sentence stimuli, i.e., whether phonologically similar words would be also activated in the *non-target* language, among Russian-English bilinguals using an eye-tracker. A specific test of the input-switch account of bilingual spoken language comprehension, that is, as the theory that states that bilinguals can deactivate one language module while using the other, requires that the speech input be restricted to only one of the bilingual's languages (Spivey & Marian, 1999). The same Russian-English bilinguals were tested accordingly in one of their languages in separate sessions (Marian & Spivey, 2003a; Spivey & Marian, 1999). However, it was thought necessary to ensure that the

participants did not realise that they were tested their bilingualism so as to reduce the chance of their activating the non-target language, thus minimising the chance of interference from that language (e.g., Grosjean, 1998, 2008). Thus, Marian and Spivey (2003b) investigated different groups of participants chosen from the same population, who then took part in an English L2 and a Russian L1 experiment respectively.

The participants were shown a cross at the centre and four objects at each corner of a board, one of which was the target they were supposed to choose, after hearing an instruction such as *Poloji marku nije krestika* (*Put the stamp below the cross*) in the Russian condition. There were interlingual-distractor-present and interlingual-distractor-absent conditions. In the interlingual-distractor-present condition, a distractor word which shares word-initial syllable (*marku*, an inflected form of *marka*, which is *stamp* in Russian) was presented with the target stamp (*marka*). The names of the other two (filler) objects (disk (*disket*) and keychain (*brelock*)) had no common feature with the target object in both Russian and English. In the interlingual-distractor-absent condition, there was no interlexical competition between the target (*marka*) and the three distractors (ruler (*lineika*), disk (*disket*) and keychain (*brelock*)). A third condition, a within-language competition condition was introduced in Marian and Spivey's (2003a, 2003b) studies, in which the target and its competitor were in one and the same language (e.g., target: *marker*, competitor: *marble*, in an L2 English condition). The eye-tracker recorded the participants' eye movements after hearing an instruction and the ratio of trials on which eye movements were made to the competitor object relative to a filler object served as the dependent variable.

Across the three studies, the bilingual participants were found to make more eye movements to within- (e.g., a plum when hearing *plug* in the L2 English condition) and between-language (e.g., a marker when hearing *marku* (stamp) in the L1 Russian condition)) competitors than to filler objects, suggesting that lexical competition occurs both within- and between-language conditions when bilinguals are presented with spoken sentences. Although the same phenomenon of the within-language

competition was observed in the three studies, the between-language competition occurred differently, that is, it was found in both of the bilinguals' languages (Marian & Spivey, 2003a; Spivey & Marian, 1999), whereas it appeared in the monolingual-mode condition, particularly when the task was carried out in their L2 English (Marian & Spivey, 2003b). That is to say, the L2 was interfered with by the L1, a more dominant and stronger language, however, the L1 was not interrupted by the L2, a less proficient and weaker language.

Similar results have been reported by Weber and Cutler (2004) and Blumenfeld and Marian (2007). With the same eye-tracking paradigm, Weber and Cutler (2004) also found that between-language competition was manifest not when the Dutch-English bilinguals performed the task in their stronger L1 (Dutch) (e.g., target *deksel*, competitor *desk*), but when in their weaker L2 (English) (e.g., target *panda*, competitor *pencil*). They concluded that native phonemic categories capture second-language input even when stored representations preserve a second-language distinction and lexical competition occurs greater for non-native than for native listeners. In the similar vein, Blumenfeld and Marian (2007), on German-English and English-German bilinguals, found between-language competition, again, not when the task was administered in L1 English (among English-German bilinguals) (e.g., target *hen*, competitor *Henne* in German), but when in L2 English (among German-English bilinguals) (e.g., target *desk*, competitor *Deckle*, *lid* in English). Speech perception in the more dominant L1 seems to be resistant to an influence of a less proficient L2, but not the other way around, and that this asymmetry especially holds when the participants are unaware that their bilingualism is being tested (de Groot, 2011, p. 194).

The effects of sentence context and L2 (French) proficiency on parallel language activation during spoken language comprehension in naturalistic sentential contexts have been reported by Chambers and Cooke (2009). They used spoken stimuli at the sentence level with a sentence context manipulation in which different predicate terms were used to create semantically restrictive and nonrestrictive sentences. In the restrictive sentence condition (e.g., *Marie va nourrir la poule* [Marie will feed the

chicken]), the predicate is congruent only with the target object (e.g., *poule*, chicken in English), but not with an English competitor word that has an initial phonological similarity (*pool*). In the nonrestrictive condition (e.g., *Marie va décrire la poule* [Marie will *describe* the chicken]), the predicate is congruent with both the target and the competing noun (i.e., the predicate *describe* can take both *chicken* and *pool* as a direct object). The target (e.g., *poule*) and competitor (e.g., *pool*) were selected as they are interlingual near-homophones that have fully discrete meanings across languages, but still share various phonological features. The participants' L2 was used as the active language in their experiment since previous studies (e.g., Blumenfeld & Marian, 2007; Marian & Spivey, 2003a, 2003b; Spivey & Marian, 1999; Weber & Cutler, 2004) have found that this L2 listening condition induces interlingual competition. L2 proficiency among the participants in their study did not predict the extent to which the interlingual competitor is considered as the target noun is heard, that is, proficiency does not provide a separate source of control over parallel language activation. The participants were found to more frequently look at competitor objects in the nonrestrictive sentence condition, whereas this was not the case in the restrictive condition. It is suggested that sentential constraints (provided by predicates) restrict consideration at an early stage of sentence processing to only contextually appropriate lexical candidates in both the active and inactive languages (Chambers & Cooke, 2009).

Thus, the results of the above-mentioned studies lead to the conclusion that spoken L2 words (the weaker, less proficient language) cause language non-selective phonological activation in bilingual mental lexicon, and data from eye-tracking studies suggest that spoken L1 words (the more dominant, stronger language) do not activate the phonological representations of L2 words that have similar phonological characteristics (de Groot, 2011, p. 195).

Up to the present, the N400 and P600 are the ERP components most frequently observed in bilingual language comprehension studies where both visual and auditory stimuli are presented (e.g., Kutas & Hillyard, 1980; Kutas et al., 1984; Osterhout & Holcomb, 1992; Kaan et al., 2000). *Components* are positive and

negative voltage peaks found in an ERP and they differ in polarity, latency and in distribution (topography) on one's scalp (Rugg & Coles, 1995). Modulations in the amplitude or the latency of a component as a function of experimental manipulation are referred to as ERP effects (Hahne & Friederici, 2001). The N400 is a negative component in the ERP signal elicited by content words, which is thought to reflect the working of a neural mechanism that attends to the semantic integration of words in context. The effect is typically larger for words congruent with the context than for contextually incongruent words. This difference is called the N400 effect (de Groot, 2011, p. 44). In the first study, Kutas and Hillyard (1980) demonstrated that sentences which ended with a word which could not be semantically integrated into the preceding sentence context, e.g., He spread the warm bread with *socks*, evoked a wave-form in the ERP that was more negative than that for a correct control word. This difference had a centro-parietal scalp distribution and reached its maximal activity about 400 ms after the onset of the presentation of the critical sentence-final word (Hahne & Friederici, 2001). The P600, another ERP component that has been consistently reported in correlation with syntactic processing, is a positive component with a latency of about 600 ms and generally a centro-parietal maximum (*ibid.*). The P600 can be observed in processing sentences with a syntactic violation, e.g., *Boris persuaded to fly* (Harley, 2008, p. 301), and *The cats won't eating the food that Mary leaves them* (Osterhout & Nicol, 1999). There is yet another ERP component which has been identified to occur during language comprehension and which seem to reflect the structural analysis of sentences. It is called LAN (left anterior negativity), named after its topography and polarity. It is detected early on in the signal, mostly 300 to 500 milliseconds after stimulus onset, however, when it is distinguished even earlier, between 100 and 250 milliseconds after stimulus onset, it is called ELAN (early left anterior negativity) (e.g., Hahne & Friederici, 1999, 2001, as cited in de Groot, 2011, p. 163).

In their study, Hahne and Friederici (2001) compared L2 listeners with native listeners in the processing of spoken L2 sentences which were either correct, semantically incorrect, syntactically incorrect or both semantically and syntactically

incorrect, and recorded ERPs to find differences in each sentence condition. Their findings indicate that sentences with semantic violations, e.g., *The volcano was eaten*, induce an ERP pattern similar to that of native listeners (a centro-parietal N400-effect) and correct sentences, e.g., *The bread was eaten*, elicit a greater positivity in L2 learners than in native listeners, possibly reflecting greater difficulties in syntactic integration. When listening to sentences with syntactic anomalies, e.g., *The ice cream was in-the eaten*, L2 learners did not show significant modulations of the syntax-related ERP components usually seen in native listeners, i.e., the early anterior negativity and the P600 effect. Processing both semantically and syntactically incorrect sentences, e.g., *The door lock was in-the eaten*, gave rise to a right anterior-central negativity, which would suggest that the right prefrontal cortex supports the processing of conceptual-semantic information whereas the left prefrontal cortex subserves the processing of lexical-semantic information (Bierwisch & Schreuder, 1992). Activation in the right frontal cortex has been found to be associated with the processing of conceptual-semantic information during the processing of non-verbal meaningful material such as visual scenes (Brewer et al., 1998) and meaningful sounds (Opitz et al., 1999, both as cited in Hahne & Friederici, 2001).

Following Hahne and Friederici (2001), Hahn (2001) compared spoken sentence comprehension (German) between native German listeners and Russian listeners who had learned German as an L2 for about six years with similar materials and methods used in Hahne and Friederici (2001). She found that an N400 was elicited by semantic violations (e.g., *Der Ozean wurde geschlossen* (*The ocean was being closed*)) in both groups, but with a reduced amplitude and a longer peak latency in the L2 group. Differences between the two groups were seen in various aspects. Among the L2 listener group, the N400 effect was more marked when processing correct sentences (e.g., *Die Tür wurde geschlossen* (*The door was being closed*)) and expanded to frontal electrode sites. The N400 component appeared about 100 ms later among the L2 listeners compared to the native listeners. Hahn interpreted these

results as indicating that the semantic integration of the sentence final word was more difficult for the L2 listeners than for the native listeners.

In processing sentences with a syntactic violation (e.g., *Das Geschäft wurde am geschlossen* (*The shop was being on closed*)), an early anterior negativity was seen in the native German group, but not in the L2 group, implying that the L2 listeners did not process syntactic category information and its integration into the existing phrase structure in the same way as the native listeners did. There was another slight delay with the P600 in the L2 group although the effect was similar for both groups, which the author suggests that similar processes of syntactic integration are carried out in both groups. Comparing performances among participants with different L1s (Russian, Japanese, and French) in similar experiments (Hahn, 2001; Hahn & Friederici, 2001; Isel al., 2000), Hahn (2001) asserts that the ERP responses vary systematically depending on L2 proficiency and that with increasing proficiency late syntactic processes reflected in the P600 appear to come into play.

Since there have been findings that the age of acquisition selectively influences bilingual cerebral organisation of syntax (e.g., Wartengurter et al., 2003) and the ultimately attained level of L2 proficiency selectively influences bilingual cerebral organisation of semantics (e.g., Perani et al., 1998, p. 1841), although this interpretation does not seem to be verified in all experimental conditions (de Groot, 2011, p. 434), caution needs to be taken when determining whether results from brain imaging studies can be generally applicable to the general bilingual population. As the participants in Hahne & Friederici's (2001) study were late Japanese learners of German (the start of learning German was at a mean age of 21), their proficiency of German was intermediate (a mean self-rating was 3.5 out of 6 = equivalent to native speaker) and their exposure to German was only 29 months on average, it is no surprising that they did not find similar phenomena found in native speakers when the participants were presented with, e.g., sentences with syntactic anomalies. Although it would be impossible to find bilinguals who possess balanced proficiencies in all domains of linguistic skills in their two languages, Hahne & Friederici (2001) showed that in case of late-learned bilinguals with intermediate

proficiency they indicate right hemisphere involvement in processing L2 spoken sentences which have less meaningful and syntactically congruent units.

The role of right hemisphere has been also discussed in the dichotic listening studies (e.g., Obrzut et al., 2001; Shankweiler, 1966) where they have found that the right hemisphere deals with the processing of musical stimuli and nonverbal content of the stimuli such as the emotional tone. Albert and Obler (1978) had suggested that the right hemisphere could be particularly involved in early stages of L2 acquisition (as cited in Obler et al., 2007, p. 23). Greater right hemisphere involvement found in bilinguals has been suggested, not to be attributable to the effect of bilingualism, but rather to treat as the use of compensatory strategies based on pragmatic tracks when proficiency of one language is lower (e.g., a situation that occurs when the L2 is learned or acquired) (Paradis, 1990, 1992, 1994, 2003, 2008, as cited in Gómez-Ruiz, 2010). Thus, it is plausible that bilinguals who started learning their L2 at a later stage of their life and are still at an early stage of acquiring the L2, are far from both native speakers and early-learned bilinguals with high proficiency, in the speed of processing L2 spoken sentences and the relevant locations of the processes at the neurocognitive level.

With highly proficient Dutch-English bilingual participants whose L2 proficiency was properly assessed with reliable objective measures (the Oxford Placement Test (Allan, 1992) and a nonspeeded lexical decision test (Lemhöfer et al., 2004; Meara, 1996) and whose onset of bilingualism was relatively earlier (after age 10) than the above-mentioned participants, FitzPatrick and Indefrey (2010) investigated whether the delayed N400 effects, which are detected when there is a semantic violation in L2 language comprehension, would be the result of intralingual lexical competition and/or interlingual lexical competition. The listening stimuli they used were sentences where the sentence-final word was (a) semantically congruent (e.g., The goods from Ikea arrived in a large cardboard *box*) and (b) semantically incongruent (e.g., He unpacked the computer, but the printer is still in the *towel*) or semantically incongruent but initially congruent due to sharing initial phonemes with (c) the most probable sentence completion within the L2 (e.g., When we moved house, I had to

put all my books in a *bottle*) or (d) the L1 translation equivalent of the most probable sentence completion (e.g., My Christmas present came in a bright-orange *doughnut* (initial overlap with “doos” where *doos* is Dutch for *box*). The authors recorded ERPs of the participants who listened to each of these sentences.

Although the authors did not include native German listeners as a control group, what they found was consistent with the previous findings in that the N400 effects were delayed among L2 listeners (approximately 490 ms). The participants indicated an N400 effect in each of the semantically incongruent conditions (conditions b and c) and the N400 effect was significantly delayed to the L2 words which appeared at the end of each spoken sentence stimuli. Their results also replicate peak and onset latency delays of the N400 to semantically incongruent words with initial phonemes which match those of semantically congruent words (*bottle* in condition c) in comparison to fully incongruent words (*towel* in condition b) for L2 listening. As native listeners do, L2 listeners find the initial phonemes as congruent with the sentence context, i.e., books are supposed to be put not in a bottle, but in a box in “When we moved house, I had to put all my books in a *bottle*,” and later notice the semantic incongruity. This would indicate that those L1 competitor words that are initially congruent with the sentence context are not considered when bilinguals listened to sentences in L2, and suggest that L2 listeners are capable of semantically integrating words in speech before a unique lexical candidate is identified (FitzPatrick & Indefrey, 2010).

Bilingual listeners would want to understand spoken speech as proficiently as native listeners do, however, this can not be the case despite these similarities found in these ERP studies. Behavioural data of these studies explicitly demonstrate that bilingual listeners are significantly worse than native peers at comprehension, for example, in background noise (e.g., García Lecumberri & Cooke, 2006; García Lecumberri et al., 2010; Rogers et al., 2006). Five possible reasons have been stated by Grosjean (2013, pp. 32-33) as for differences which could negatively influence bilingual listeners’ listening performance.

First of all, bilinguals possess and process not just one language but two or more, hence processing mechanisms (e.g., monolingual processing and bilingual processing) and linguistic knowledges (e.g., L1 and L2 knowledges and code-switches) are at least double in quantity (can be more with another language added), and they are active and available when one of them is being used (Crinion et al., 2006; Dijkstra et al., 1999; Marian et al., 2003; Rodriguez-Fornells et al., 2005). Second, depending on each language's linguistic construction, the way those linguistic features (phonetic, lexical, syntactic) function may be different to a certain degree. For example, the perception of tones may be crucial for comprehension in one language but not in the other. Third, bilingual speech can be monolingual, that is, all aspects of the speech are in that one language only (i.e., monolingual mode), or be bilingual, that is, what bilinguals hear may include code-switches or borrowings (i.e., bilingual mode). Grosjean (1998) explains that the bilingual's language mode influences perception and the speed of access to one or two lexicons, and the language mode itself is influenced both by the language user's presuppositions and by language intermixing (whether there are words of one or more languages embedded in the stimulus list) (Dijkstra, 2005, p. 196). Fourth, when one of their languages is processed, the processing mechanisms may be inevitably influenced by the other language due to coactivation of the other language(s). Finally, bilinguals are rarely fluent in all of their languages (e.g., for different purposes, in different domains of life, and with different people), therefore, there will be differences in the linguistic knowledge of their languages, which will have an impact on speech perception and comprehension. There can be different ratios of processes between languages (i.e., some languages may be less well processed than others) and, within a language, a lack of vocabulary, for example, may influence perception and comprehension. This is clearly manifested when comparing native listeners and bilingual listeners in speech perception in more real-life, adverse conditions, i.e., in a noisy background (e.g., García Lecumberri et al., 2010; Rosenhouse et al., 2006), where bilingual listeners virtually always perform less well than native counterparts. Ezzatian et al. (2010) show some other factors causing the difference in listening

performance between native listeners and non-native, L2, listeners, such as duration of exposure to the non-native language, degree of similarity between the native and non-native languages, knowledge of the non-native language vocabulary and grammatical structure, frequency and extent of non-native language use.

Psycholinguistic approaches to bilingual speech comprehension have been utilised to investigate at both behavioural and neurocognitive levels how bilingual listeners perceive phonemes, words and sentences while encountering these internal (i.e., linguistic knowledge of the two languages) obstacles. For bilingual listeners, listening to L1 words activates L2 candidates, and listening to L2 words activates L1 candidates (e.g., Marian, et al., 2003). This seems to be the case with bilinguals regardless of their L2 proficiency (intermediate or advanced), the onset of bilingualism (early or late) and their L1 (e.g., Russian-English, Chinese-English) (e.g., Thierry & Wu, 2007). The next section examines a model of bilingual speech perception called the Bilingual Interactive Model of Lexical Access (BIMOLA) and other previously proposed models.

2.3.4 *Models of bilingual speech comprehension*

Models of the bilingual lexicon, as explained below, can generally account for the results of bilingual word-recognition experiments performed in and out of context that show that context plays a minimal role in constraining the activity of the language not in use (Kroll & Dussias, 2013, p. 221). Models of bilingual language comprehension have been advanced mostly in the domain of reading, that is, *visual* word processing, such as the Bilingual Interactive Activation (BIA) model (Dijkstra & van Hueven, 1998) and the BIA+ (Dijkstra & van Hueven, 2002), which will be briefly discussed here. It is indeed principally written language that has been investigated rather than spoken language (Grosjean, 2008, p. 201). One that has ever attempted to model bilingual *auditory* word processing is the Bilingual Interactive Model of Lexical Access (BIMOLA) (Grosjean, 2008; Léwy & Grosjean, 1996), which is the main focus of this section. All of these models have their root in an

interactive activation (IA) model of speech perception such as the TRACE model (McClelland & Elman, 1986).

The BIA model (Dijkstra & van Hueven, 1998) was originally developed as a computational model of visual word recognition (de Groot, 2011, p. 197). It uses a language tag or node to convey information to the lexical nodes of the corresponding language membership of the word (Dunn & Tree, 2012). All nodes at the word level are interconnected and they can mutually inhibit each other's activation, which is called lateral inhibition. The model is restricted to the orthographic processing aspect of visual word recognition, encoding information about letters and visual word forms in its structure (Thomas & van Hueven, 2005, p. 206).

The BIA+ model (Dijkstra & van Hueven, 2002), an extension from the BIA model, includes phonological and semantic lexical representations, and postulates that the activation level of a lexical candidate is based on phonological similarity to the input word. Although language nodes are also present in the BIA+ model, words of the other language cannot be inhibited. The orthographic, phonological semantic, and language node representations are part of the identification system of the BIA+ model (Thomas & van Hueven, 2005, p. 212).

The BIMOLA, the only model that has attempted to model the bilingual processing of spoken words (Grosjean, 2008; Léwy & Grosjean, 1996), has three levels of nodes which are the auditory features, phonemes, and the spoken forms of words. The feature level node is a unified node shared by the two languages, whereas the phoneme and word nodes are organised independently in each language and also as one large system. This contrasts with the BIA model, for which the two languages are not distinguished at the letter and word levels other than by the fact that L1 and L2 words are connected to different language nodes (Thomas & van Hueven, 2005, p. 210). After receiving an acoustic wave, the auditory features of it are processed, which activate phonemes, that, in turn, activate the spoken forms of words. The features are suggested to include a number of allophonic variants, consisting of 43 consonants, 26 vowels, 6 glides, and 8 diphthongs (83 sounds in total) in English and French. They are divided into three features: binary features; ternary features; and

multivalued features. Léwy and Grosjean (1996) and Grosjean (2008, p. 205) have added three new features that represent length, aspiration, and instability. The connections between the phoneme and word nodes are bidirectionally activated, whereas the activation connections between the feature node and phoneme node are bottom-up. Recognition of words is influenced by top-down information such as external information about the listener's language mode and higher linguistic information. Although the language pair that has been investigated is English and French, the authors claim that the BIMOLA is meant to be a general bilingual model regardless of language pair (Grosjean, 2008, p. 205).

A good number of studies examining the recognition of visual words and the comprehension of spoken words have come to a conclusion that it is in effect impossible for bilinguals to turn a blind eye/deaf ear to the unattended language, whether it is their L1 or L2 (e.g., Marian & Spivey, 2003a, 2003b; Thierry & Wu, 2007). Critically, even highly proficient bilinguals who are able to process each language quite skilfully show parallel activation of both languages (Kroll & Dussias, 2013, p. 218). It has been found in many studies that alternatives in both of a bilingual's languages are active, at least briefly, when they are asked to recognise words in only one of their languages (e.g., Dijkstra, 2005; Jared & Kroll, 2001; Marian & Spivey, 2003a, 2003b). Hence, the recent consensus as for bilingual lexical access is that information of both languages is activated in *parallel* (e.g., Dijkstra et al., 1998; Kroll et al., 2012), even when the task is administered solely in one of their languages and even when the bilingual participants are highly proficient in their L2 (e.g., Schwartz et al., 2007; Thierry & Wu, 2007). As for the cerebral organisation of the bilingual's two languages, it is most likely that two languages are represented as different microanatomical subsystems in the same areas of the brain, and that differences in the brain organisation of their languages are rather qualitative than quantitative in terms of metalinguistic knowledge and implicit linguistic competence (Gómez-Ruiz, 2010).

Consequently, although attention needs to be directed to the mechanism of more practical aspects of bilingual speech comprehension, the BIMOLA may be the only

model that is ultimately able to rationalise the current evidence of language-nonselective phonological activation, as it was specifically developed as a model for spoken word recognition and it allows excitation of lexicons of both languages. Therefore, the BIMOLA seems the most natural candidate to explain language-nonselective phonological effects (de Groot, 2011, p. 199).

New model of bilingual speech processing

Following connectionist models such as BIA+ (Dijkstra & van Hueven, 2002) and BIMOLA (Grosjean, 1988, 1997, 2008) presented above, through computational modelling of the language system, Shook and Marian (2013) have recently proposed the Bilingual Language Interaction Network for Comprehension of Speech (BLINCS), which they suggest a novel model of bilingual spoken language processing which captures dynamic language processing in bilinguals and a combined connectionist and distributed model of bilingual spoken language comprehension. Unlike those connectionist models of bilingual language processing, the BLINCS combines features of both distributed (i.e., a distributed neural network model that uses unsupervised learning to capture bilingual lexical access) and localist (i.e., localist, connectionist models like BIA+ and BIMOLA that can provide insight into steady-state instances of the bilingual processing system) models in an effort to accurately simulate the natural process of bilingual spoken language comprehension. The natural processes the authors mean are the involvement of the integration of auditory and visual information, the integration of previous experience and both linguistic and environmental cues to supply clues about language membership when hearing a word in one of the two languages, and influences on the bilingual system from long-term features such as the age of acquisition, language dominance and language proficiency, and short-term features such as recent exposure to the L2.

The BLINCS model is suggested to incorporate multiple interconnected levels of representation - phonological, phono-lexical, ortho-lexical and semantic - and each level in the model is individually constructed using the self-organising map

algorithm. In addition, the model considers simulation of the influence of visual information on language processes through connections to the phonological and semantic levels (for detailed descriptions of these levels of representations, see Shook & Marian, 2013). These representations interact with and inhibit each other within and between levels. Within levels, language-specific and language-shared representations employ the same network space, hence communication (and competition) between languages is the product of both lateral links between translation-equivalents, and proximity on the map (i.e., items that are distributed together are simultaneously active, but also inhibitory with each other). Between levels, bidirectional excitatory connections are computed via Hebbian learning (i.e., associative learning, in which simultaneous activation of cells leads to pronounced increases in synaptic strength between those cells (Doidge, 2007; Hebb, 1949)), in which connections between items that activate together are strengthened through self-updating algorithms.

Shook and Marian (2013) used English and Spanish spoken stimuli to train their model. At the phonological level, the model presupposes a shared phonological system, in which there is no clear representation between Spanish and English phonemes. It is nevertheless possible that words that have language-specific phonetic features in one language (so not shared across languages) activate that language only at the phono-lexical level. Hence, it appears likely that two languages that have highly contrasting, non-overlapping phonological accounts might exhibit more dissociation at the phonological level. A bilingual's two languages are assumed to be separated but integrated at the lexical level in the model. Words are separated at the phono-lexical level in accordance with the phono-tactic probabilities of the input into language regions where cross-language items that have highly overlapping phonological features (e.g., cognates and false-cognates) are likely to be placed at the boundaries. A separate but integrated ortho-lexical structure similar to the phono-lexical level is suggested. The degree of difference between the two languages' orthographies influence the structure of the ortho-lexical level. Greater integration of ortho-lexical forms between languages whose orthographies are very similar (e.g.,

Spanish and English) may be observed. At the semantic level, the BLINCS model assumes a single semantic level with a shared set of conceptual representations across languages.

Language activation in bilingual speech comprehension has been modelled in the BLINCS. Through simulations of language activation in the model, the authors claim that the model is able to account for and making predictions as for (1) the activation of onset competitors both within- and between-languages and (2) rhyme competitors both within- and between languages, (3) the impact of ortho-lexical information on phono-lexical processing, (4) the interaction between semantic and phono-lexical representations, and (5) increased or faster activation for cognates and false-cognates. These processes can be influenced by visual information found in the natural listening environment. A probable means of separating a bilingual's two languages is also suggested in the model. It is possible, the authors state, by combining the self-organising maps which capture the relationships between representations (e.g., phonological, phono-lexical, ortho-lexical, and semantic) by putting them in physical space, and a connectionist activation framework, which seizes how these representations interface both within and across levels of processing.

Although the authors mention that expansion and refinement of the model will be necessary, they assert that the BLINCS model is successful in describing many phenomena in bilingual speech comprehension. Notwithstanding, it has been pointed out that present models of bilingual language processing (BIA+ and BIMOLA) including the BLINCS do not consider a role for top-down, domain-general cognitive processes in the inhibition of transiently activated lexical competitors, which have been found to modulate the time-course of spoken language comprehension among bilinguals (Mercier et al., 2014). Consideration of the role of individual differences in both domain-general inhibition and language-specific mechanisms may lead to more complete accounts of bilingual speech processing. Mercier et al. (2014) encourage investigations of bilingual language processing in more *cognitively demanding situations* (e.g., the Simon task, Bialystok et al., 2008;

Bialystok et al., 2004), which would contribute to the exploration of the hypothesis that the regular recruitment of domain-general inhibitory mechanisms to cope with the demand of managing their two languages leads to a strengthening of these mechanisms. This notion of incorporating cognitively demanding situations into experiments on bilingual speech comprehension seems particularly important and relevant to the current dissertation. Studies which have investigated bilingual speech processing integrating the concept of executive/inhibitory control are presented in the following section.

2.4 Working memory

In surviving for nearly forty years, the concept of a multicomponent working memory has provided a useful theoretical framework for investigating a wide range of human activities (Baddeley, 2010, p. R140). Bilingualism research is no exception in that cognitive advantages among bilinguals have been ingeniously investigated with WM tasks and the concept of WM has contributed to the understanding of the mechanisms of bilingual language processing, learning, memory, behaviours, brain development, and ageing, across different age and language groups (e.g., Abutalebi et al., 2000, 2008; Abutalebi & Green, 2007; Bialystok, 1999, 2001, 2005, 2009; Crinion et al., 2006; Emmorey et al., 2008; Kroll et al., 2012; Wang et al., 2009).

Definition of working memory

An exemplary definition, based on definitions provided by twenty-three authors, Miyake and Shah (1999) have presented the following definition of working memory:

WM is those mechanisms or processes that are involved in the control, regulation, and active maintenance of task-relevant information in the service of complex cognition, including novel as well as familiar, skilled

tasks. It consists of a set of processes and mechanisms and is not a fixed 'place' or 'box' in the cognitive architecture. It is not a completely unitary system in the sense that it involves multiple representational codes and/or different subsystems. Its capacity limits reflect multiple factors and may even be an emergent property of the multiple processes and mechanisms involved. WM is closely linked to long-term memory (LTM), and its contents consist primarily of currently activated LTM representations, but can also extend to LTM representations that are closely linked to activated retrieval cues and, hence, can be quickly reactivated. (p. 450)

Although studies on visual word processing have taken up most of the attention, if not all, in the bilingual language processing research, the situation is changing, that is, there has been an increasing number of studies on bilingual auditory language processing which consider the role WM plays in spoken speech perception and comprehension (e.g., Abutalebi et al., 2007; Bialystok, 2001, 2009; Hugdahl et al., 2009; Soveri et al., 2011; Vaid, 1986). Influences from bilingual experiences on cognitive/executive functioning have been also extensively investigated with WM tasks (e.g., Bialystok, 1986, 1999; Bialystok et al., 2007; Botvinick et al., 2001; Miller & Cohen, 2001; Posner & Rothbart, 2007). This section gives a general review of WM studies and the role of WM in language processing, and describes how executive and attentional control are executed in bilingual language processing.

2.4.1 *History of working memory*

The concept of working memory famously proposed by Baddeley and Hitch (1974) has been implemented, since its advent, extending from its origin in cognitive psychology to many areas of cognitive science and neuroscience, and been applied within areas ranging from education, through psychiatry to paleoanthropology (Baddeley, 2010). Baddeley and Hitch used the term, *working memory*, to describe the short-term memory system, which is involved in the temporary processing and

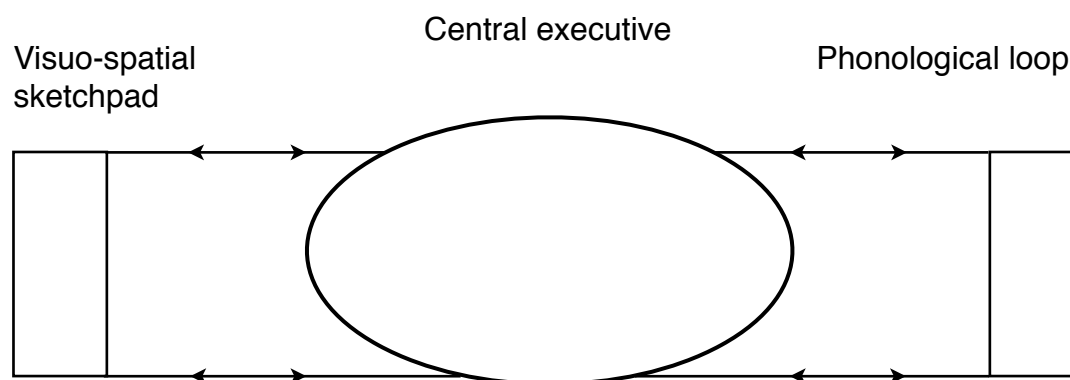


Figure 2.2. The Baddeley and Hitch's model of working memory proposed in 1974.

information, and suggested that working memory plays an important role in everyday cognitive activities including reasoning, language comprehension, long-term learning, and mental arithmetic (Gathercole & Baddeley, 1993, p. 2).

The model of working memory proposed in 1974 (Baddeley & Hitch, 1974), shown in Figure 2.2, was a multicomponent model which posited three components: the central executive, aided by two short-term storage slave systems, the visuo-spatial sketchpad, and the phonological loop, all of which were assumed to be limited in capacity. The core component of WM, the central executive (CE), which is assumed to be an attentional-controlling system, achieves various different tasks including coordination of information from two or more slave systems and allocation of inputs to the two slave systems, and retrieval of information from long-term memory. The CE has been suggested to be involved in cognitive tasks such as mental arithmetic (Hitch, 1980), recall of long lists of digits (Baddeley & Hitch, 1974), logical reasoning (Baddeley & Hitch, 1974), random letter generation (Baddeley, 1966), and language comprehension (e.g., Clark & Clark, 1977; Daneman & Carpenter, 1980, 1983; Oakhill et al., 1986). As Baddeley (2012) himself recently states in his review, *“Working Memory: Theories, Models, and Controversies,”* however, theoretical progress on the CE was slow and he was reluctant to pursue the CE because of its probable complexity, and the crucial importance of its attentional capacity (*ibid.*, p. 6).

Indeed, much of the earlier work concentrated on the two slave systems, since they appeared to offer more amenable problems than did the CE (Baddeley, 2002). However, there were a number of important advances in understanding this component of WM made in the 1980s. The only one directly relevant piece of research, which Baddeley himself (2012, pp. 6-7) refers to, matching the concept that the principal role of the CE is the attentional control of action, is one by Norman and Shallice (1986). They suggested that there are two rather different ways where action is controlled. One of which is based on well-learned or “automatic” habits or schemata, demanding little in the way of attentional control. Schemata can be hierarchically organised. Skilled drivers, for instance, will have a driving schema that activates subroutines such as steering, gear-changing, and breaking schemata. During the act of driving, the driving schema will be activated and all its subroutines primed, so that the sight of red lights at the rear of the car ahead should be adequate to provide the environmental cue to trigger the breaking schema (Gathercole & Baddeley, 1993, p. 6). This source of control can be overridden by a second process, the supervisory attentional system (SAS) (Norman & Shallice, 1986), which responds to situations that are not capable of being handled by habit-based processes, for example, dealing with the closure of a road on one’s normal route (Baddeley, 2012, p. 7).

The SAS is a conceptualisation of the executive component similar to the CE based on the concept of spreading activation. In this model, automatic activation of schemata driven by goals and contextual information provides the base for information intended for different levels and spreading activation. This leads to higher activation of some schemata and inhibition of others. In some situations, the limited capacity SAS intervenes by redirecting and giving schemata appropriate priorities, inhibiting those inconsistent with a current goal (Ilkowska & Engle, 2010, p. 297). Later advancement of the theory of the CE in the later years, where the executive component of the CE, controlled attention, is referred to as *working memory capacity* (WMC) (e.g., Cowan, 2005), is presented after descriptions of the two slave systems, and development of the model of working memory (Baddeley,

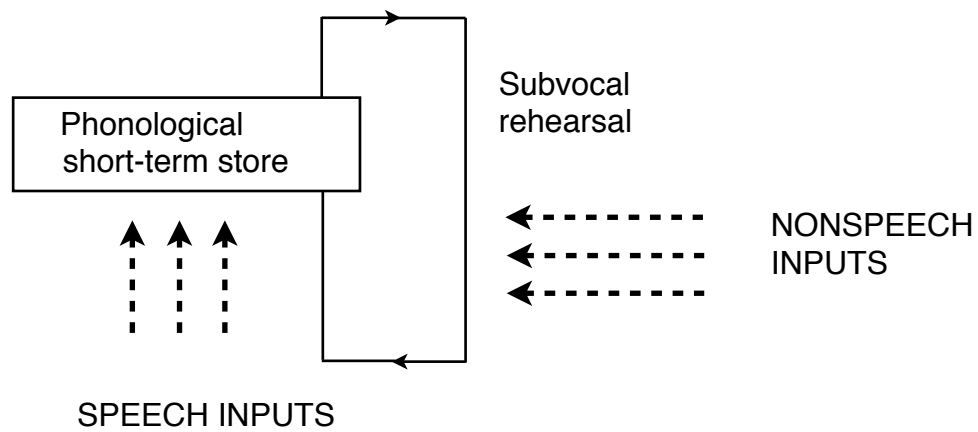


Figure 2.3. A reproduction of the phonological loop model based on Baddeley (1986).

2000, 2012), since the concept of WMC is of most relevance and importance to the current research.

The phonological loop

The phonological loop (see Figure 2.3) is perhaps the simplest and most extensively investigated component of WM (Baddeley, 1992), possibly because of the availability of a few simple tools such as the phonological similarity, word length, and suppression effects (Baddeley, 2012, p. 11). The phonological loop is specialised for storing verbal material, comprising the phonological short-term store and subvocal (articulatory) rehearsal. The phonological store can hold acoustic or speech-based information for one to two seconds. Articulatory rehearsal functions to maintain the information in the phonological store beyond the two-second limit. Since the act of articulatory rehearsal can be conducted without apparent articulation, non-phonological features in, e.g., printed words or pictures, are construed into their phonological form through the articulatory process so that they can be transferred to the phonological store. On the contrary, processing spoken speech does not require articulatory rehearsal, but is thought to have the direct access to the phonological store (Gathercole & Baddeley, 1993, p. 8).

The existence of the phonological loop structure, the phonological store and the rehearsal process, has been evidenced in the following experimental phenomena.

The phonological similarity effect

Immediate serial recall is poorer when items to be recalled are similar in sound or articulatory characteristics (Baddeley, 1997, p. 53). Therefore, PGDVCD will be harder to remember than RHXKWY (Conrad & Hull, 1964; Baddeley, 1966). Hearing and repeating dissimilar words such as “pit, day, cow, pen, rig,” is easier than a phonologically similar sequence such as “man, cap, can, map, mad” (Baddeley, 1992; Conrad, 1964). The phonological similarity effect is presumed to occur because the phonological store is based on a phonological code; hence similar items will have similar codes. Thus, recall of these items will require discriminating among the memory traces, where similar traces will be harder to distinguish, leading to a poorer recall performance (Baddeley, 1997, p. 53). The finding that the phonological similarity effect occurs after reading as well as after hearing the items, suggests that visually presented items are converted to phonological codes and held within the phonological store for subsequent oral recall. Conversion of visual stimuli into phonological codes is thought to involve subvocal articulation of the items. Similarity of meaning does not result in semantic confusions with immediate, serial ordered oral recall, indicating that this subsystem does not reflect semantic coding (Baddeley, 1992, p. 558).

The irrelevant sound effects

Colle and Welsh (1976) asked their participants to remember sequences of visually presented items in silence or in the presence of irrelevant speech sounds, either white noise or a language with which the participants were unfamiliar, and found that only the spoken stimulus interfered with their recall performance, which is an effect that was independent of the volume of the irrelevant speech stimuli (Colle, 1980). The

semantic characteristics of the items were not found important. The irrelevant and unfamiliar language was just as distracting as words in their native language and nonsense syllables as distracting as meaningful words. These results are interpreted under the assumption that all spoken stimuli gain mandatory access to the phonological memory store (Baddeley, 1992, p. 558). The irrelevant speech therefore disrupts the current contents of the phonological storage component of the phonological loop (Gathercole & Baddeley, 1993, p. 13).

The word-length effect

Immediate verbal memory performance is directly influenced by the spoken length of memory items (Baddeley et al., 1975) measured by asking participants to read out words of different lengths as quickly as possible. The spoken length is the time required to utter a word, i.e., the articulatory duration of the memory items, not simply the number of syllables they contain. Recall performance was compared between bisyllabic words with relatively short spoken durations (e.g., *wicket*, *bishop*) and those with long durations (e.g., *harpoon*, *Friday*). The effects of these spoken durations were manifested in the results that recall was significantly better for the “short” words than the “long” ones. The authors argued that articulatory rehearsal takes place in real time, so that words that take longer to produce also take longer to rehearse, thereby losing fewer of the short items from the phonological store as a consequence of decay and enabling the participants to recall more short words than long ones in a given time (Baddeley et al., 1975). The word-length effect is also seen in differences in digit span when participants are tested in different languages, that is, languages in which numbers tend to have long vowel sounds or more than one syllable take longer to rehearse, leading to shorter digit memory spans (Ellis & Hennessey, 1980). They found that children who spoke English had a better digit span compared to those who spoke Welsh merely because English digits take less time to articulate and to rehearse than Welsh digits.

Articulatory suppression

Disruption of the phonological loop is possible when overt or covert articulation of an unrelated item is demanded. This is seen in experiments where a participant is given a standard digit span task and at the same time asked to continuously say a word such as “the.” The consequent digit span is likely to be considerably lower than when there is no coarticulation (e.g., Baddeley et al., 1984; Murray, 1965). Articulatory suppression is assumed to occur because the coarticulation of an unrelated item dominates the articulatory control process, thus preventing it from being used either to maintain material already in the phonological store, or convert visual material into a phonological code (Baddeley et al., 1984). According to the working memory model, the disruptive effect of articulatory suppression arises because it prevents participants from rehearsing as depicted in Figure 2.3. Suppression also removes the phonological similarity effect for visually presented materials but this is not the case when presentation is auditory (Baddeley et al., 1984). The result is interpreted as indicating that spoken material gains obligatory access to the phonological store, whereas visual material needs to be subvocalised if it is to be converted into phonological codes and held in the phonological store (Baddeley, 2012, p. 8).

The function of the phonological loop

A good deal of research on the role of the phonological loop has shown that the phonological loop seems to play a significant role in learning to read (e.g., Jorm, 1983), language comprehension (Baddeley & Wilson, 1988; Vallar & Baddeley, 1984, 1987; Vallar & Shallice, 1990), long-term phonological learning (e.g., Baddeley et al., 1988), and acquiring a vocabulary in both one’s first and second language (e.g., Ellis, 1996; French, 2006; Gathercole & Baddeley, 1989, 1990; Service, 1989).

Vallar and Baddeley (1984, 1987) found a patient with a very pure deficit in short-term phonological memory and embarked on investigating whether the phonological loop would be important for language *comprehension*. They found that although PV was able to comprehend and detect errors in simple sentences (e.g., *Sailors are lived on by ships*). However, when the material requires verbatim retention of information in complex sentences with many intervening words, her comprehension performance was found to deteriorate. Since the problem in processing and understanding long sentences is characteristic of short-term memory deficits (Vallar & Shallice, 1990), Vallar and Baddeley (1984, 1987) argued that the results would suggest that the phonological input store plays a role in comprehension, however, probably only for particularly complex or demanding material. Hence, one speculative interpretation is that it merely acts as a supplementary back-up which plays a secondary role in comprehension, but is not of primary importance (Baddeley, 1997, p. 65). The possibility of the function of the phonological loop in language comprehension seems to be moderate. It is hard to argue convincingly that the capacity to interpret such extremely complex sentences (e.g., *Ships are believed, and with some considerable justification, to often be lived on by sailors*) is likely to have conferred a sufficiently major biological advantage as to justify the evolution of an apparently specialised system such as the phonological loop (Baddeley, 2007, p. 16).

It was then hypothesised that the phonological loop might possibly contribute to language *learning* (Baddeley et al., 1988), in both L1 (e.g., Gathercole & Baddeley, 1989) and L2 (e.g., Papagno et al., 1991; Papagno & Vallar, 1992). Gathercole and Baddeley (1989) found among children who were classified as language disordered in their first language that they were poorer at the simple repetition task of nonwords with varying lengths and complexities, known as the nonword repetition task (e.g., Gathercole et al., 1994) used to estimate phonological working memory (e.g., Adams & Gathercole, 1995, 1996; Gathercole & Baddeley, 1989). The authors interpreted this finding as suggesting that a phonological loop deficit might be at the root of their other language problems. Baddeley, Gathercole and Papagno (1998) later proposed

that the primary function of the phonological loop is the processing of novel speech input, incorporating the ability to retain and repeat a phonological sequence and therefore support the learning of the phonological forms of new words, and that it is the phonological loop that is the primary language learning device.

Papagno et al. (1991) found that by disrupting phonological processing, i.e., concurrent tapping or articulatory suppression, learning of foreign language vocabulary was hindered, although little influence on native language paired-associate learning was confirmed. Papagno and Vallar (1992) further explored the effect of the other two variables, i.e., phonological similarity and word length effects, on foreign language learning. Although influences from these effects were observed on foreign language learning, neither of them affected the rate of learning pairs of native language words (Baddeley, 2007, p. 17). These results suggest that the phonological loop plays a role in learning new phonological forms. Service (1989) studied young Finnish children who were learning English as a second language and assessed their cognitive skills, then investigated correlations between the cognitive skill measures and their performances on a range of tests of English two years later. He found significant correlations between the children's English skills and cognitive abilities assessed with tasks including measures of nonverbal intelligence and those of nonword repetition capacity. Here again, nonword repetition capacity, which is assumed to depend on short-term phonological storage, was clearly the best predictor of subsequent success. Thus the evidence supports the view that short-term phonological memory is crucial in the acquisition of vocabulary (Baddeley, 1992).

The visuo-spatial sketchpad

The other component of WM proposed by Baddeley and Hitch (1974) is the visuo-spatial sketchpad, which is specialised for the processing and storage of visual and spatial information, and of verbal material that is subsequently encoded in the form of imagery (e.g., Logie et al., 2000; Saito et al., 2008). The phonological loop was assumed to deal with the maintenance of speech-based information, including digits

in the digit span test, whereas the visuo-spatial sketchpad was assumed to perform a similar function in setting up and manipulating visuospatial imagery (Baddeley, 1992). More recently, Baddeley (2003) states that this subsystem of working memory serves the function of integrating spatial, visual, and possibly kinaesthetic information into a unified representation which may be temporarily stored and manipulated.

The concept of the visuo-spatial sketchpad was initially motivated by Phillips (1974), who investigated the visual-memory store with matrix stimuli and demonstrated that recall accuracy collapsed as the number of cells to be remembered increased. Baddeley, Grant, Wight, and Thomson (1975), as the first systematic investigation of the visuo-spatial sketchpad, asked their participants to memorise a series of instructions that in one case could be stored in terms of an elaborated visual image, while in the other relied on purely verbal coding (Baddeley et al., 1975). In their experiments, a version of the imagery technique (Brooks, 1967) was used as a memory task that demands storage of visual information. The memory task was conducted without any distraction or while engaging in a concurrent spatial tracking task where the participants had to keep a stylus in contact with a moving light spot. Memory performance based on imagery was hampered by the tracking task, whereas that on the purely verbal task was not (Baddeley et al., 1975). Baddeley and Lieberman (1980) conducted a further study to explore whether the nature of the store was visual or spatial. In their study, while performing the Brooks task, the participants were blindfolded and required to trace a sound (*spatial* but not visual) or detect the brightening of their visual field (*visual* but not spatial). The authors found that the spatial task was still disturbed by the tracking task, but not by the verbal task, however, the brightness judgement showed a slight tendency in the opposite direction, leading them to conclude that the system was spatial rather than visual (Baddeley, 2012, p. 13). Research following theirs has demonstrated that the storage may be principally visual as represented by colour and shape (Logie, 1986), or possibly motor or kinaesthetic (Smyth & Pendleton, 1990), depending on the memory task (Baddeley, 2003). The nature of rehearsal in the sketchpad is also

uncertain. Logie (1995, 2011) has suggested a distinction between a “visual cache,” which is a temporary visual store, and a spatial manipulation and rehearsal system, which he calls the “inner scribe,” although the precise nature of visuo-spatial rehearsal remains unclear (Baddeley, 2012, p. 13).

The function of the visuo-spatial sketchpad

Tasks involving visuo-spatial manipulation have long formed an important component of intelligence batteries, and have tended to be used as selection tools for professions where visuo-spatial planning and manipulation are regarded as important, such as engineering and architecture (Baddeley, 1997, p. 82). As an example of the role of the visuo-spatial sketchpad, Baddeley (1997, p. 82, 2007, p. 89) refers to Hatano and Osawa’s (1983a, b) studies where they demonstrated that Japanese expert abacus users were able to perform calculations by simply imagining the abacus, and were furthermore able to use the imagined abacus to aid their memorisation of number sequences. An abacus was imported and introduced into Japan from China in the 1570s (cf.; The League of Japan Abacus Associations: <http://www.shuzan.jp>), it was in the early days learned among samurais and merchants, then taught to their children at *terakoya* school (a kind of primary school for children of the uneducated class, where they taught reading, writing and arithmetic before the *Meiji* Restoration, cf.; Wisdom English-Japanese, Japanese-English Dictionary). There have been abacus competitions where abacus users perform feats in which they add and subtract up to fifteen numbers, each comprising five to nine digits (Baddeley, 1997, p. 82). Learning an abacus has been one of the popular after-school activities among school children in Japan.

Hatano and Osawa (1983a, b) found that expert abacus users were able to memorise approximately sixteen digits forward and fourteen digits backward, however, their performance on memorising digits, letters and fruit names was disrupted by a concurrent visuo-spatial task, that is, remembering a drawing of an object, indicating that their performance depended on the use of the visuo-spatial

component of working memory (Baddeley, 2007, p. 89). The authors suggested three tactics which enable abacus experts to perform the high-level arithmetic task. First, they might well be using the sketchpad component of working memory. Second, they may be using a chunking approach. Third, they register digit items in their long-term memory (Baddeley, 1997, p. 82).

Another example of the use of the visuo-spatial sketchpad can be found in a study by Garden et al. (2002) where the participants were given a task to learn an unfamiliar route through the streets of a medieval Italian city. At the same time, they were required to perform a concurrent spatial tapping task on a hidden keyboard, or perform articulatory suppression. Those who said that they used a mental map, were more disrupted in their navigation by the concurrent visuo-spatial task, whereas those who depended on landmarks were more affected by articulatory suppression (Baddeley, 2007, p. 89).

Development of the working memory model

Components of working memory, the phonological loop, the visuo-spatial sketchpad, and the central executive, proposed in the initial model (Baddeley & Hitch, 1974), had received a significant amount of attention and have been continuously researched in many areas of cognitive science, including mainstream cognitive psychology, neuropsychology, neuroimaging, developmental psychology, and computational modelling. However, there have always been phenomena that did not fit comfortably within the Baddeley and Hitch model (Baddeley, 2000). The initial model is capable of explaining a great deal of data, nevertheless, the attempt to limit its storage capacity to the visuo-spatial and verbal subsystems has created a number of significant problems (Baddeley, 2007, p. 147). The search for the process whereby working memory and long-term memory (LTM) interact was also shown complex. The situation was further entangled by the attempt to treat the central executive as a purely attentional system with no storage capacity (Baddeley & Logie, 1999).

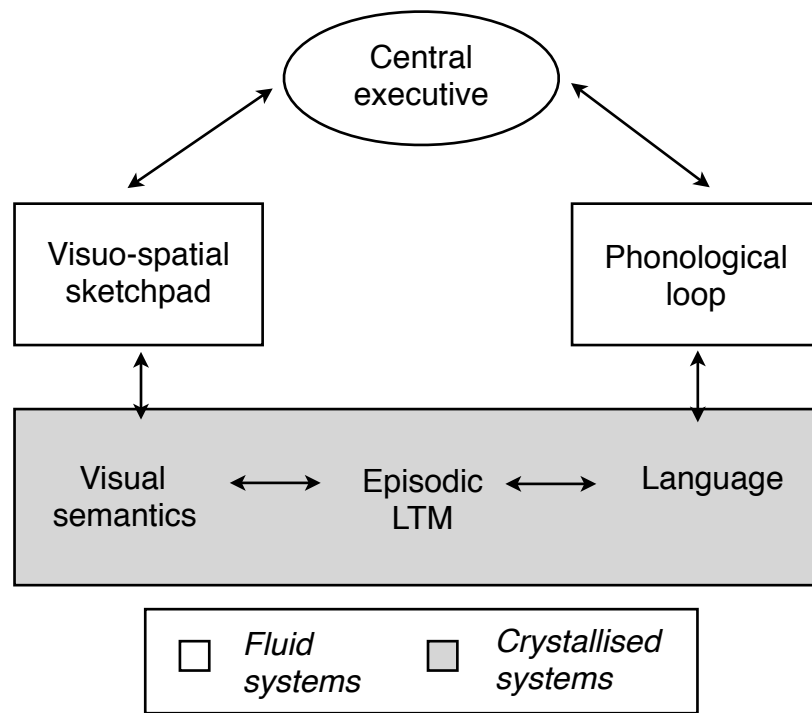


Figure 2.4. A modified model of working memory that has links between working memory and long-term memory (LTM) (Baddeley, 2000).

The problems derived from findings that patients with clear short-term phonological deficits indeed have specific deficits in long-term phonological learning, e.g., learning the vocabulary of a new language (Baddeley et al., 1998). These findings rejected the initial idea that working memory and LTM were entirely independent from each other (Baddeley & Hitch, 1974). Baddeley et al. (1998) found further evidence to support the view that the phonological loop is linked to performance on vocabulary learning among children. It was manifested among patients with phonological loop deficits, who have great difficulty in learning new vocabulary. Although little researched, it appears plausible that the visuo-spatial sketchpad has a similar function, possibly in acquiring visual semantics, i.e., nonverbal semantic information, such as the typical colours of objects or how certain animals or people move, together with implicit knowledge of the physical and mechanical world. With this speculation, Baddeley (2000) suggested a provisionally modified model of working memory as shown in Figure 2.4.

In that model, it became clear that the phonological loop plays an important role in long-term phonological learning, that is analogous to the development of vocabulary learning in children and to the speed of foreign language vocabulary learning in adults (Baddeley, 2000). Baddeley added the concept of the theory of fluid and crystallised intelligence proposed by Cattell (1963) to his model. Crystallised cognitive systems, those in the grey rectangle, are liable to amass long-term knowledge, that is, language and semantic knowledge. Fluid cognitive systems, those in the unclouded rectangle, are assumed to deal with attention and temporary storage, and are themselves unchanged by learning, other than indirectly via the crystallised cognitive systems (Baddeley, 2000).

After the temporary modification of the working memory model, there appeared to be significant problems with its applications, that is, problems with the proposed idea that storage capacity was limited to the visuo-spatial and phonological slave systems. From a series of studies (e.g., Baddeley, 2001; Schank, 1983; Vallar & Baddeley, 1984; Wilson & Baddeley, 1988), Baddeley (2000) assumed that there would be a temporary store that is capable of holding complex information, manipulating it and utilising it over a time scale far beyond the assumed capacity of the slave systems of WM. A further problem with integrating information from more than one source and the failure to address the concept of conscious awareness, became apparent from a study by Baddeley and Andrade (2000) in which the participants were asked to maintain auditory or visual images and rate their vividness, while simultaneously performing tasks chosen to disrupt selectively either the visuo-spatial or phonological slave systems. They suggested the involvement of the relevant systems in conscious awareness, and in addition an ample role for LTM and for the central executive. Furthermore, the original model was confronted with findings from clinical patients and the concept of chunking. When a sequence of words form a meaningful sentence, it is usually possible to retain sixteen words or more (Baddeley et al., 1987), by chunking meaningful units (Miller, 1956). Chunks are made by integrating information from LTM. What matters is not the number of words, but the number of chunks that form the meaningful chunks. Then, where are

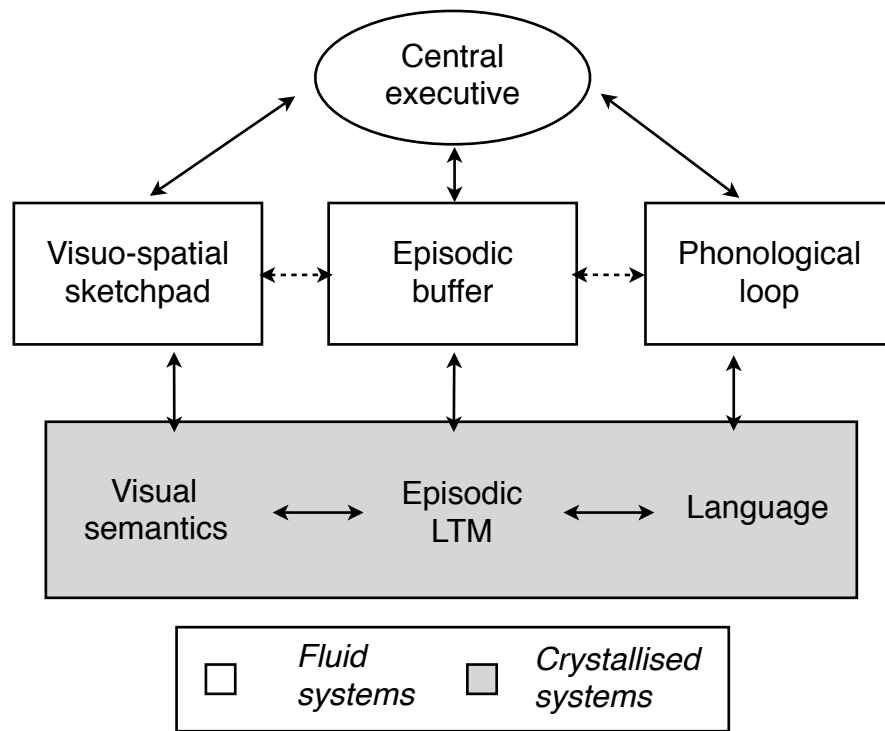


Figure 2.5. A modified model of working memory that has the episodic buffer as the fourth component which serves as a modeling space that is separable from LTM, but forms an important stage in long-term episodic learning (Baddeley, 2000). The dotted lines are likely direct links between the subsystems (Baddeley, 2007, p. 147).

they stored? The patient called PV, a patient with a very pure deficit in short-term phonological memory discussed earlier, had a sentence span of five, although, of course, it is indeed far smaller than fifteen or so, that is to be recalled by matched control subjects (Vallar & Baddeley, 1984). A sentence span is estimated in the sentence span task, a variant of Daneman and Carpenter's (1980) reading span test, where the participant is required to read a series of sentences silently and make a judgement about the plausibility of each sentence (e.g., Baddeley et al., 1985; Duff & Logie, 2001; Waters & Caplan, 1996). Nevertheless, this could not have been seen if the chunks were stored in the phonological loop as it is disadvantageous for a patient with short-term phonological memory deficit. Although the visual and verbal slave systems of the WM model do offer a plausible account of a wide range of data, evidence from patients with short-term memory deficits, from the resistance in serial

recall to articulatory suppression, and from the recall of prose, all suggest the need to assume a further back-up store (Baddeley, 2000).

In order to solve these problems, Baddeley (2000) put forward the concept of an episodic buffer, the fourth component of the working memory model, which he described as a limited-capacity temporary storage system, and a process or mechanism for synergistically combining information from various subsystems into a form of temporary representation. The model in which the episodic buffer provides a temporary interface between the two slave systems (the phonological loop and the visuo-spatial sketchpad) and LTM is illustrated in Figure 2.5.

The episodic buffer, as the name tells, is episodic in nature in the sense that it holds episodes by which information is integrated across space and possibly extended across time. An episodic memory is about a specific event that occurred at a particular time and place, such as one's memory of getting a traffic ticket or observing a car accident (Tulving, 1972). The buffer interacts with a range of systems, each incorporating a different set of codes.

There is assumed to be conscious access between the buffer and the central executive. The executive can also control the content of the store by responding to a given input, whether it is perceptual, from other components of working memory, or from LTM (Baddeley, 2000). To sum up, it is presupposed that the episodic buffer be a temporary storage system that is able to combine information from the phonological loop, the visuo-spatial sketchpad, long-term memory, or from perceptual input, into a coherent episode, and that the buffer be the basis of conscious awareness (Baddeley, 2007, p. 148). Although direct links between the buffer and the sketchpad, and the loop were not originally implied in the initial model (Baddeley, 2000), there has been some evidence to support the speculation (Baddeley, 2007, p. 148). Baddeley (2007, 2012, 2013) later adds dotted lines between the episodic buffer and the other two subsystems, indicating that the buffer serves to integrate information from the three subsystems and the central executive to each other, and to information from perception and LTM (Baddeley, 2013).

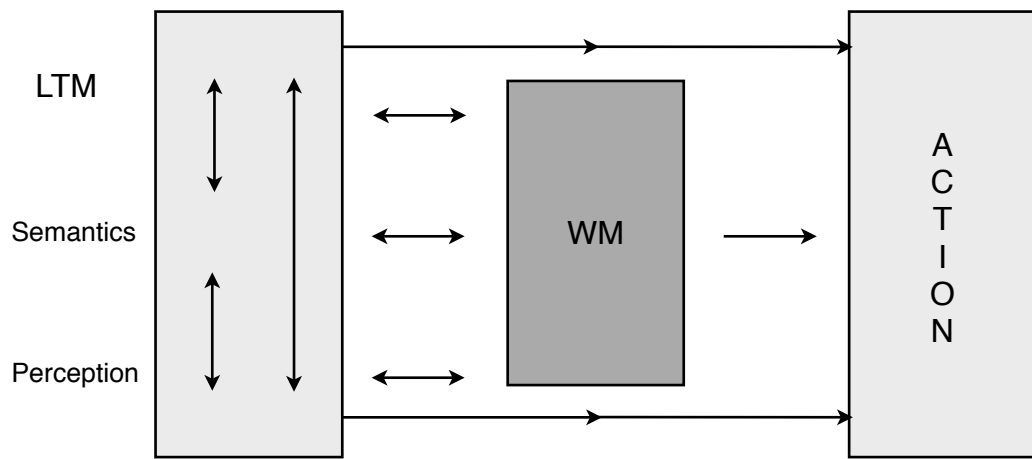


Figure 2.6. Baddeley's recent view of the complex and multiple links between working memory (WM) and long-term memory (LTM) (Baddeley, 2012, p. 18).

In Miyake and Shah's (1999) definition of working memory, working memory and LTM are independent from, but readily interact with each other. Baddeley (2012, p. 18) also agrees with this view that working memory is not merely activated LTM, and maintains that working memory involves the activation of many areas of the brain that involve LTM. Baddeley (*ibid.*) sees working memory as a complex interactive system that is capable of providing an interface between cognition and action, an interface that is able to handle information in a range of modalities and stages of processing, that is depicted in Figure 2.6. As outlined in the figure, incoming information is processed by systems which themselves are altered by LTM.

A tentative model of working memory

Baddeley (2012, pp. 22-24) introduces a tentative model of working memory that is not considerably different from the speculation initially proposed in Baddeley and Hitch's (1974) model and has more speculative detail, as shown in Figure 2.7. Along with the model, Baddeley asks questions, although not easily answered, as for each component of working memory, which are shown in Table 2.1. Baddeley (2012) states that, in order to provide an interactive unitary system that mediates between perception, LTM, and action, it is important to know what working memory does *not* do, that is, accepting negative results, which could lead to answering these questions.

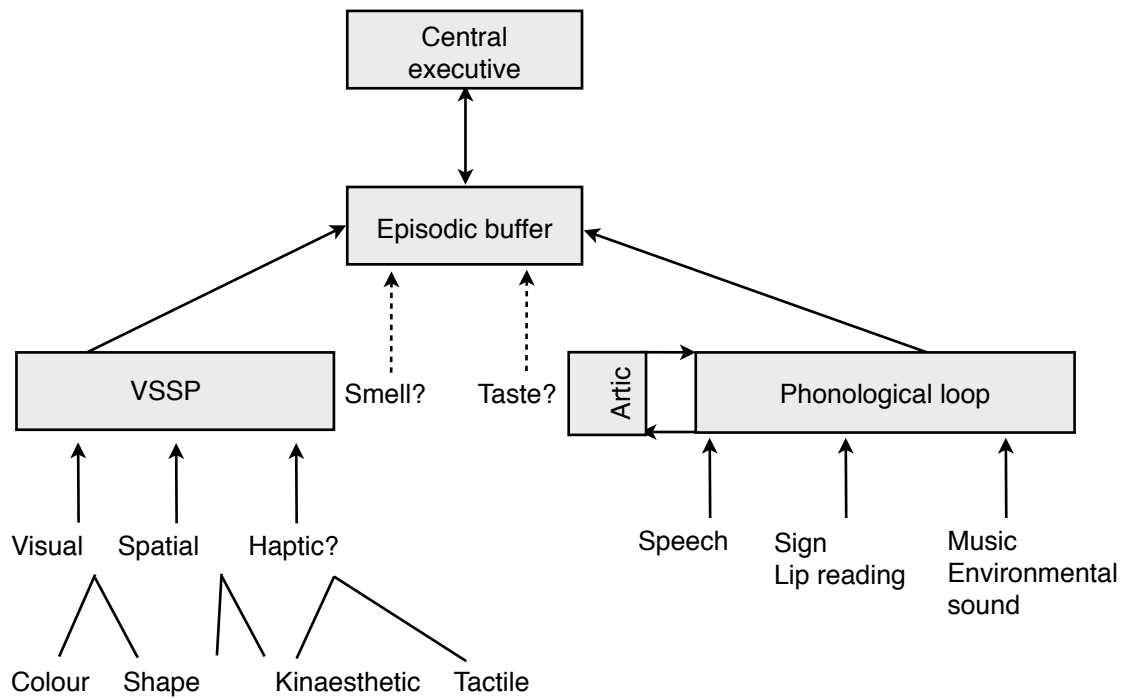


Figure 2.7. Baddeley's tentative view of the flow of information from perception to working memory. VSSP, visuo-spatial sketchpad (Baddeley, 2012, p. 23).

Table 2.1. *Speculations of the Components of Working Memory and Questions Raised by Them* (Baddeley, 2012, pp. 22-23)

Components of working memory	Questions
Central executive: an attentional system and comprises a number of executive functions	<ul style="list-style-type: none"> - How many of executive functions, and how are they organised and interrelated? - Whether it is needed to worry about precisely what is being inhibited and whether this differs between individuals?
Episodic buffer: operates according to the principle of attentionally based refreshing, and provides access to conscious awareness	<ul style="list-style-type: none"> - How it can be measured? - To what extent is this limited by number of chunks and to what extent by similarity between chunks? - Whether we are not directly aware of the other subsystems but only of their products when registered in the buffer?
Phonological loop:	<ul style="list-style-type: none"> - Whether subvocal rehearsal atypical of other types of rehearsal? - To what extent is the loop used for remembering non-verbal material such as music or environmental sounds?
Visuo-spatial sketchpad: the visual and spatial aspects seem to be explicitly separable but linked within the sketchpad	<ul style="list-style-type: none"> - Whether the speculation of the sketchpad is true of haptic, tactile, and kinaesthetic memory? - What is the mechanism of visuo-spatial rehearsal? - Whether pursuing the link between the sketchpad and LTM would show equally useful?

2.4.2 *The concept of working memory capacity as a control of attention*

When people are engaged in everyday tasks such as cooking, driving, reading a newspaper, watching TV, listening to the radio, writing an essay, delivering a presentation, and so forth, most of the processes involved in each of these tasks seem to be so automatised that no one would, as it is not usually necessary to, realise that they are unconsciously paying their attention to specific aspects of these tasks and paying no attention to anything unrelated to them, so as to achieve the task goal. On the contrary, imagine a situation where someone is driving his car while getting dressed, brushing his teeth, shaving his face. Even if driving is already a cognitively demanding task, this person tries to do each of these tasks while doing the driving at the same time. Whether this person eventually got injured or not, he was successfully doing each task while driving.

What seems to be involved in the maintenance of attention to driving (the target task) presumably safely while brushing his teeth, whether cleanly or not, etc. (irrelevant tasks) is *working memory capacity* (WMC) (Cowan, 2005; Engle, 2002, 2010; Engle et al., 1999, p. 104), that primarily has to do with one component of the working memory system, i.e., *controlled attention* (e.g., Posner & Snyder, 1975; Schneider & Shiffrin, 1977), that is assumed to be implemented by the central executive (Baddeley & Hitch, 1974). Engle, Kane and Tuholski (1999) regard working memory as a system comprising 1) a store in the form of long-term memory traces active above threshold, 2) processes for achieving and maintaining that activation, and 3) controlled attention. They assume that WMC is not concerned with storage or memory as such, but rather with the capacity for controlled, sustained attention in the face of interference or distraction (p. 104). WMC is most important when goal-related information must be actively maintained to guide response selection, especially if viable but contextually inappropriate response alternatives are also available (Engle & Kane, 2004).

Hypotheses regarding the concept of working memory capacity

Pascual-Leone (1970), an early neo-Piagetian, stated that maintaining schemata active calls for attentional control or mental energy and that the amount of mental power or *M*-space increases developmentally as a result of biological or epigenetic factors (as cited in Conway & Engle, 1996). Neo-Piagetians were researchers who developed the view that if performance on short-term memory tasks would demonstrate what an individual had in his or her mind, the capacity might be linked to the capacity for thought in many more complex conditions. Pascual-Leone (1970) developed a mathematical theory that incorporated a parameter *M*, the number of schemata that could be activated concurrently (Cowan, 2005, p, 26). His view was expanded by Case (1974) to suggest that differences in *M*-space are related to both individual and developmental differences in cognition. Case (1974) maintained that increases in *M*-space occur not as a result of an increase in attentional resources but as a result of a speed-up in mental operations as they become automatised (Conway & Engle, 1996). In other words, individual differences in WMC appear since some people do all mental operations faster and more efficiently than others do, and this is called the *general processing hypothesis* (Engle et al., 1992), which is an approach to the relationship between WMC and higher-level cognition.

Measures of WMC have been developed and implemented to investigate the contribution of controlled attention to higher-cognitive tasks such as language comprehension (Daneman & Carpenter, 1980), mathematics (Adams & Hitch, 1997), following directions (Engle et al., 1991), and writing (Benton et al., 1984). For example, performance on Daneman and Carpenter's (1980) reading span test (RST), in which participants are asked to read aloud sets of 2-6 sentences and recall the final word of each sentence after reading each set, has been found to correlate well with overall measures of reading comprehension such as the Verbal Scholastic Aptitude Test (VSAT) (e.g., Daneman & Carpenter, 1980; Hannon & Daneman, 2001). Hence, the RST predicts efficiency in reading comprehension as both the RST and reading task involve reading, which is referred to as the *task-specific hypothesis*. As a

consequence, good readers should be able to recall more of the final words than unskilled readers since they have more automatised reading operations. A key prediction of the task-specific hypothesis is that a WM task will exhibit predictive validity only when it captures the specific skills involved in the tested task (Hambrick & Engle, 2003, p. 185).

More recently, it appears that a consensus has been reached on the *general capacity hypothesis* that holds that measures of WMC capture domain-general information-processing capabilities that can be brought to bear on many tasks (Hambrick & Engle, 2003, p. 185). In essence, individuals with high WMC will have more attentional resources available for performing a task regardless of the characteristics of the task (Conway & Engle, 1996). According to Engle, Kane, and Tuholski (1999), WMC is thought to reflect primarily domain-general executive attention. Conway, Kane, Bunting, Hambrick, Wilhelm, and Engle (2005) regard WM as a multicomponent system responsible for active maintenance of information in the face of ongoing processing and/or distraction. Active maintenance of information is the result of converging processes, that is, domain-specific storage and rehearsal processes and domain-general executive attention. Furthermore, the extent to which maintenance depends on domain-specific skills versus domain-general executive attention is different as a function of individual ability, task context, and ability \times context interactions (p. 770). Thus, a key prediction of the general capacity hypothesis is that operations unique to a particular working memory task (e.g., reading sentences aloud) are unimportant to a large extent in explaining the relationship between WMC and cognitive performance. Instead, WM tasks are thought to be imperfect indicators of a construct involved in the execution of a wide range of tasks (Hambrick & Engle, 2003, p. 185).

Available evidence and results from computational modelling in predicting and explaining individual differences in WMC (e.g., Daily et al., 2001), and connectionist approaches investigating through the circuitry of the prefrontal cortex (PFC) and associated structures (e.g., O'Reilly et al., 1999), suggest that, although performance on complex span tasks may be influenced by domain-specific

processing competencies, they share features in their measurement of a *domain-free (general)* ability to control attention (Feldman-Barrett et al., 2004).

The central executive and working memory capacity

WMC has been linked to the efficiency of operation of the central executive (Baddeley & Hitch, 1974), and has been used as a measure and an index of controlled attention in various cognitive psychological studies (e.g., Beaman, 2004; Elliott & Briganti, 2012; Elliott et al., 2007; Kane & Engle, 2003; Kane et al., 2004; Sörqvist, 2010). Baddeley (2012, p. 20) states that the most extensively developed theoretical account of WMC is that proposed by Engle and his colleagues (e.g., Engle et al., 1999; Engle & Kane, 2004). An emphasis of their theory is placed on the importance of *inhibitory processes*, which they maintain are critical to keeping the memory content intact from prospective interference. Much of the research on WMC has been derived from a combination of individual differences and experimental approaches, characteristically testing a large group of participants and then dividing them into two subgroups (i.e., high-span subjects (HSSs) and low-span subjects (LSSs)) depending on their WMC (Baddeley, 2012). HSSs are those in the highest quartile of WMC and LSSs in the lowest quartile. This experimental design is called an extreme-groups design, that investigates the magnitude of the relationship between WMC and some other task (Conway et al., 2005; Cowan, 2005, p. 45). The concept of WMC is restricted to the role of the central executive and inhibitory processes in various domains have been consistently represented in the brain (e.g., Elliott, 2002; Osaka & Osaka, 2007). It has been also known that several brain areas that are anatomically networked with the dorsolateral prefrontal cortex (DLPFC), which supports sufficient maintenance of attention on the target information (Osaka & Osaka, 2007), are important for success in WM tasks (Kane & Engle, 2002), which is described more in detail below. Even from this brief review of WMC investigations, it seems legitimate, although it may be a part of the role WM plays,

that the concept of WMC, i.e., controlled attention and inhibitory processes, is pivotal in understanding cognitive processes involved in higher-cognitive tasks.

Feldman-Barret, Tugade, and Engle (2004) state that WMC reflects individual differences in the ability to control attention associated with the central executive aspect of working memory. The authors elucidate that individual differences in WMC are reflected in the ability to simultaneously keep goal- or task-related representations active in mind; engage in a controlled, plan-based search of memory and effortful retrieval of additional goal- or task-related representations as needed; monitor for potential conflicts when there are competing response options; and resolve this conflict by inhibiting actions and suppressing the activation of unwanted information in conditions that are complex, full of distractions, or that pull for response competition (p. 560). Unsworth and Engle (2007) describe that individual differences in WMC spring mainly from variations in the ability to maintain information active in primary memory and from efficient search and retrieval of information kept in the secondary memory (as cited in Ilkowska & Engle, 2010, p. 18). William James (1890) referred to the primary memory as the trailing edge of the conscious present, and the secondary memory to the vast amount of information accumulated from a lifetime of experience. Unsworth and Engle (2007) indicate that LSSs have more difficulty in maintenance and retrieval of information, and might also make more errors.

Individual differences in WMC are reflected in the levels of efficiency in performance on various tasks and the execution of the cognitive control processes of the central executive has been found to be located in the prefrontal cortex (PFC) in studies with macaque monkeys (e.g., Fuster & Bauer, 1974; Goldman-Rakic, 1987) and those with human patients with brain damage (e.g., Ferreira et al., 1998; Frisk & Milner, 1990; Verin et al., 1993) and healthy human participants (D'Ardenne et al., 2012; Duncan et al., 2000). Functions of WMC appear to rely on the dorsolateral prefrontal cortex (DLPFC) (e.g., Engle et al., 1999; Miller & Cohen, 2001) and so this brain region should be important to executive attention (Kane & Engle, 2002). The macaque subjects were gathered from those in the following three conditions: 1)

those with surgical lesions to circumscribed brain areas; 2) those with implants that temporarily deactivate brain areas through cooling or electrical current; and 3) those with electrode implants to allow for single-cell recordings (Kane & Engle, 2002). The human participants with brain damage were those who suffered stroke, tumours or tumour resection, aneurysm repair surgery, or penetrating head wounds (*ibid.*).

When WMC is studied with the monkey subjects, so-called delay tasks such as delayed response, delayed alternation, and delayed matching-to-sample, and the self/externally ordered memory task have been used. An object or spatial stimulus is briefly shown on a computer screen and then disappears from the view for some delayed duration. After the delay, the monkey has to detect the target stimulus from among distractors. Monkeys under the conditions mentioned above demonstrate chance levels of recall on these tasks (Engle et al., 1999, p. 117). WMC, that is the controlled attention in spite of interfering information, is assessed with the monkey subjects by either placing an opaque physical barrier between the subject and the stimuli, thus requiring eye fixation on a non-target location, or by requiring a maintained reaching response to a non-target location (e.g., Funahashi et al., 1989), thus attentional focus is typically drawn away from the to-be-recalled stimuli during the delay (Kane & Engle, 2002). Successful performance on the delay tasks requires that information about the stimulus be maintained for use in the presence of distracting components in the environment, as well as in the presence of interference from prior-trial information at retrieval (*ibid.*). Overall, it has been found that it is necessary for monkeys to have intact DLPFC to perform delayed-memory tasks (e.g., Bartus & LaVere, 1977; Malmö, 1942).

Human subjects with brain damage to their PFC or DLPFC have shown severe deficits on WM tasks which require that information about the stimulus be maintained for use in the presence of distracting elements in the environment, as well as in the presence of interference from prior-trial information at retrieval (Kane & Engle, 2002), whereas patients who have their brain lesion in other parts of their brain such as the temporal lobe or posterior lobe and controls with no brain damage have not shown such deficiencies. Evidence shows that cognitive effort is more

required in WM tasks than short-term memory (STM) tasks which involve only temporary information storage and do not entail simultaneous processing of other irrelevant information, and this is implicated in more activation in the DLPFC when tackling WM tasks, but not when performing STM tasks (e.g., Dupont et al., 1993; Frisk & Milner, 1990; Smith et al., 1996). Similar results to those found in the macaque monkeys on delay tasks have been found among human patients with PFC damage, in that in delayed-response and delayed-alternation tasks with 15-second delays, they indicated noteworthy impairments compared to patients with posterior lesions and human subjects with intact brain (e.g., Baldo & Shimamura, 2000; Verin et al., 1993). In the delayed-response task, significantly more patients with PFC damage (7 out of 10) made errors, whereas only 2 of the 10 patients with posterior damage made errors and the human subjects with an intact brain made no errors.

In brain imaging studies of WM, the *n*-back task (Kirchner, 1958; Mackworth, 1959), has been used as it requires simultaneous storage and manipulation of information (Kane & Engle, 2002). One PET study used the 3-back task where participants had to respond to each stimulus object in a continuous sequence only if it matched the item shown three items ago or in another condition if the object appeared in a location that was occupied three items ago (Smith et al., 1996, as cited in Kane & Engle, 2002, p. 646). Hence, the participants were required to retain information about the target stimulus (either object or spatial information) while dealing with each new stimulus at the same time. Increased activation in bilateral dorsolateral areas 46 and 9 in both object and spatial 3-back conditions was observed compared to control conditions. Although many *n*-back studies have observed bilateral, and approximately symmetrical DLPFC activation (e.g., Braver et al., 2001; Cohen et al., 1993; Smith et al., 1996), differences in DLPFC activation have been found between object and spatial WM tasks (McCarthy et al., 1996). When presented with objects, the left DLPFC showed greater activation than the right, and when presented with locations, interestingly only the right side of DLPFC was significantly activated.

In spite of the intriguing findings, differences in the roles of DLPFC in processing object and spatial information may be due to normal individual differences. Inconsistent results come from findings where half of the subjects showed either bilateral DLPFC activation in both tasks or corresponding unilateral DLPFC activation in both tasks, whereas the other half of the subjects showed bilateral activation in one of the tasks and unilateral activation in the other (D'Esposito et al., 1998). It has to be noted that none of the subjects showed uniquely right hemisphere activation in one task and uniquely left hemisphere activation in the other (Kane & Engle, 2002). Owen et al. (2005) provide some evidence, through their meta-analysis of studies probing the *n*-back task, that the left PFC is dominant for verbal information, left dorsal premotor for spatial information, and the right PFC for object information. Nevertheless, since the *n*-back is a complex task, whether these differences were indicative of differences in storage or manipulation processes remains to be answered (Nee et al., 2013).

Research on the role of PFC in connection with WMC among healthy human subjects has focused on executive attention (e.g., Conway & Kane, 2001; Engle, 2001; Engle et al., 1999), which Kane and Engle (2002) mean “a capability whereby memory representations are maintained in a highly active state in the face of interference, and these representations may reflect action plans, goal states, or task-relevant stimuli in the environment.” They maintain that the active maintenance of information is most required in situations where there is irrelevant interference or where responses compete with other somewhat similar or even entirely different information sources. When there is no interference, it is obviously easy to retrieve task-relevant information, goals, or response plans from LTM as necessary. Nonetheless, when there is much interfering information, it is more likely to retrieve inaccurate information and response trends. Under these circumstances, active maintenance of relevant information and possibly inhibition of unnecessary information, supposedly the roles of WMC, are most crucially essential.

Findings from healthy human subjects performing the delay tasks (e.g., from 1 to 21 seconds), where they are shown human faces as stimuli, are not as conclusive as

those from non-human primates or lesion studies, in that the loci of increased brain activity are observed not only in DLPFC, but also some other networking brain areas such as anterior cingulate (Brodmann 24) circuits, and between more ventral PFC (Brodmann 47) and posterior areas 21 and 37 (e.g., McIntosh et al., 1996; Grady et al., 1998). It appears that the network between the PFC and Brodmann 37, so-called the fusiform face area (FFA), is required when processing human faces (e.g., Allison et al., 1994; Kanwisher et al., 1997). The FFA is the suggested functional and anatomical homologue to primate face-selective inferior temporal cortex (e.g., Druzgal & D'Esposito, 2003). Similar phenomena are found in studies where participants are given object stimuli or spatial stimuli. Under these conditions, little activation in the prefrontal area can be seen, instead, more activation is observable in Broca's area (Brodmann 44 and 45), more ventral (i.e., lower side) PFC areas, and/or around premotor cortex and supplementary motor areas (e.g., Jonides et al., 1993; Rowe et al., 2000; Smith et al., 1995). As evidence shows and it is well-known that verbal memory tasks activate left-hemisphere speech areas (e.g., Brown, 1976; Rasmussen & Milner, 1977), and it has been recently revealed that spatial memory processing activates the right premotor cortex, and object memory processing activates more ventral regions of PFC (e.g., Smith & Jonides, 1999). Hence, although the PFC is partially involved under these cognitively demanding conditions (i.e., delays before recall), it seems that these relatively specific brain networks are indeed necessary for processing certain types of information.

Another possible reason for these inconsistent findings, stated by Kane and Engle (2002), is that the delays were so brief, typically 3 seconds or less between the study and test sessions, that it was unnecessary for healthy human subjects to have recourse to the working of DLPFC, compared to nonhuman primates and human subjects with brain lesions. It was such a brief instance for human subjects that they were able to complete the delay tasks with minimal use of executive attention, that is the role of DLPFC. In fact, when delays are relatively longer, activation in DLPFC has been consistently seen (e.g., D'Esposito et al., 2000; Goldberg et al., 1998, as cited in Kane & Engle, 2002), which means that the longer delays can lay more cognitive

demand that has to be dealt with by DLPFC. Kane and Engle (2002) further state that these brief-delay tasks were closer to STM tasks than WMC tasks since the participants were without any distraction and were not required to process irrelevant information, both of which are the case with WMC tasks. Indeed, in PET studies (e.g., Dupont et al., 1993; Smith et al., 1996) where participants were given STM tasks which simply asked them to maintain information across short delays, there has been limited evidence of DLPFC activation. Even if activation was observed in the prefrontal area, it was seen in more ventral areas such as Broca's area and/or in premotor cortex and supplementary motor area (Engle et al., 1999, p. 118), as shown above.

To sum up the views of WM as controlled attention and findings from brain imaging studies, the DLPFC and regions to which it is networked, are critical to working memory functions, that are seen in behavioural tasks that require maintenance of information across shifts of attention. Hence, individual differences in WMC among normal individuals are mediated through individual differences in PFC functioning (Engle et al., 1999, pp. 118-119). It should be added that individual differences in WMC should best predict other capabilities when the WM-measure and the target-ability task both demand executive attention. Furthermore, bilateral patterns of DLPFC activation are most likely to be seen during memory tasks that make the highest demands on executive attention in spite of the task domain (Kane & Engle, 2002, p. 659).

Fairly recently, Ilkowska and Engle (2010, p. 302) have asserted that individual differences in WMC are most pronounced when choosing among competing responses, overriding habitual responses under situational factors, such as anxiety, or when under a high cognitive load as when performing a dual task. They briefly present brain structures that may shape the capacity of WM, which include the DLPFC, anterior cingulate cortex (ACC), and basal ganglia (BG) (*ibid.*, pp. 303-304), which have been found to underpin the functioning of WMC.

DLPFC, as has already been shown, is known to regulate goals and keep an eye on cognitive control processes such as action, planning, reasoning, decision-making, dynamic filtering of information, in addition, partitioning and consolidation of

information related to emotional functioning (e.g., De Pisapia et al., 2007; Shimamura, 2000). It is also suggested to play a role in managing miscellaneous processes, for example, withstanding interference, preserving the task goal in the face of interruption, constraining irrelevant information, and sorting out conflicts, or effects of proactive interference, that is a phenomenon where the familiar context that recently or repeatedly occurs does not allow discriminating well between new and old information (Ilkowska & Engle, 2010, p. 301). Kane and Engle (2002) confidently suggest that the aspects of executive control that are the focus of this dissertation, namely, the ability to maintain focus on a representation or goal and to block distraction, all in the presence of interference, is heavily dependent on dorsolateral prefrontal structures.

Another important brain area called the ACC is located, as the name indicates, in the anterior (i.e., near the front) part of the cingulate cortex, and this part of the cingulate cortex has been described as ‘executive’ (Vogt et al., 1992). The cingulate cortex is in the medial (i.e., in the middle) aspect of the cortex. Increased activation in the ACC has been observed particularly under conflicting situations (e.g., Barch et al., 1997; Braver et al., 2001), where subjects attempt to suppress interfering responses. A significant correlation between the ACC’s signal intensity and memory load has been found in a delayed response task (Bunge et al., 2001). Hence, the ACC is in control of monitoring and resolving conflicts when faced with conflicts (e.g., Weissman et al., 2003) and response selection (Braver et al., 2001). Simultaneous activation of the PFC and ACC has been found when engaged in conflicting tasks, in which the PFC plays a role in inhibiting irrelevant responses and the ACC in monitoring conflicts and detecting errors (Kerns et al., 2004).

Lastly, the BG, which are a set of subcortical nuclei located in the midbrain, around the thalamus (Stocco et al., 2014), have the ability to employ control during input processing and make sure that only relevant information is dealt with (McNab & Klingberg, 2007). These activities have been observed in coupling activity of the PFC and BG in WM tasks, which is seen just before excluding unrelated information.

Osaka and Osaka (2007; also their colleagues, 2002, 2004, 2007) investigated the neural substrates for focusing and shifting attention aspect of WM with their own developed reading span tests (RST) called the focused RST (F-RST) and non-focused RST (NF-RST) where subjects were required to read aloud sets of sentences and recall either focused or non-focused words presented in bold letters (e.g., Focused RST: *The child dropped food on his jacket and made **stains*** (Focus word: **stains**); Non-focused RST: *The child dropped **food** on his jacket and made stains* (Target word: **food**)), and brain activity was recorded with an fMRI. In F-RST, the target word and the word the focus of attention is paid to are the same, 'stains,' so no conflict is involved. On the contrary, in NF-RST, since the target word 'food' and focused word 'stains' do not match, subjects have to shift attention from the focus word 'stains' to the target word 'food' where inhibition of attention is required. Through their extensive research, they discovered that the ability to focus attention arises from additive SPL (superior parietal lobule) activation, which plays a role in focusing and shifting attention and supports executive control of ACC and DLPFC, and that cooperative activations of the DLPFC, ACC and SPL comprise the neural substrates of executive function (Osaka & Osaka, 2007, p. 114).

In summary, the concept of WMC is the capacity for controlled, sustained attention in the face of interference or distraction (Engle et al., 1999, p. 104), and although performance on complex span tasks may be influenced by domain-specific processing features, they have sharing features in their measurement of a domain-free (general) ability to control attention (Feldman-Barrett et al., 2004). It would be worth noting that one particularly important function of the WM system is for keeping information quickly retrievable and usable under conditions where there is interference from information that is strongly elicited by task context but that nevertheless would lead to a response inappropriate for the current task, and that WMC is not about memory per se, but it is about individual differences in executive attention (Engle, 2001, p. 312). The central executive aspect of WMC is underpinned by various brain areas and networks connecting them in human beings as well as nonhuman primates, including the DLPFC, which supports sufficient maintenance of

attention on the target, the ACC, which serves attention management, such as resolving conflict and inhibiting potential responses unnecessary for the goals of task performance, the SPL, which aids in execution of focusing attention in the regulatory system of working memory (Osaka & Osaka, 2007, p. 114), and the BG, which selects only relevant information for attention based encoding (Ilkowska & Engle, 2010, p. 304).

2.4.3 *Working memory and language*

Research on the relationship between working memory and language (e.g., L1 vocabulary acquisition, speech production, reading, and listening comprehension) had its onset in the late 1970s when Clark and Clark (1977) verified a major role of working memory in their model of spoken language comprehension. They proposed four steps used by listeners when constructing the underlying representation for sentence processing (Clark & Clark, 1977, p. 49). First, they maintain a phonological representation of the raw speech in working memory as they hear it. Second, they rapidly set out to sort the phonological representations into constituents (i.e., a group of words that can be replaced by a single word without a change in function and without affecting the rest of the sentence, Clark & Clark, 1977, p. 48), for the identification of their content and function. Third, each constituent is used to assemble a hierarchical representation of propositions of the sentence. Finally, the propositions are stored in working memory and working memory representation of the speech input is purged, thereby retaining the meaning of the message rather than the wording. These four steps are applied all in action at the same time rather than one after another. Listeners may well identify constituents while taking in new speech input, identify propositions while organising constituents, and purge memory simultaneously with many other activities (Clark & Clark, 1977, p. 49). Although not specified in their model, what they suggested as the working memory representation of the linguistically unprocessed message corresponds directly to the phonological

loop for the temporary storage of the phonological form of linguistic material (Gathercole & Baddeley, 1993, p. 202).

Kintsch and Van Dijk (1978, 1983) proposed a different model for the role of working memory in language comprehension of text. In their model, the written message is processed in cycles from left to right (or, for spoken texts, in temporal order) in chunks of several propositions at a time. They (also others such as Just & Carpenter, 1980) claimed that short-term memory capacity plays a significant role in reading and listening comprehension, and that short-term memory should therefore be an important source of individual differences in language comprehension ability. In their model, therefore, a short-term memory buffer is suggested to be used to process propositions and coherence of preceding and succeeding texts is evaluated based on the stored propositions. When a connection (i.e., an overlap) between any of the new propositions and those already retained from an earlier chunk in the buffer is found, the input is accepted as coherent. If there is not such an overlap, an inference process is initiated, requiring a resource-demanding search of all previously processed propositions stored in long-term memory in case of auditory comprehension, which puts heavy demands on the listener's resources. In their model, the efficiency of coherence processing is assumed to be constrained by capacity limitations of the short-term memory buffer, which appears to be substantiated by the general resources of the central executive rather than the more specialised phonological loop system (Gathercole & Baddeley, 1993, p. 204).

Both of these models posited the role of verbal short-term memory in processing language, i.e., processing sentences that have complex and syntactically demanding structures, that is to say, if short-term memory plays a crucial role in language comprehension, people with very low memory span should demonstrate severe difficulty in processing the meaning of language. However, this prediction has been substantially rejected by findings from cognitive neuropsychological studies (e.g., Caplan & Waters, 1990; Hanten & Martin, 2000; Vallar & Baddeley, 1984, 1987). Patients with acquired left hemisphere damage which led to severe short-term memory deficits (e.g., difficulty in repeating phrases longer than eight syllables) in

language processing were recruited. They also showed a phonological similarity effect for auditory, but not visual, material, no word-length effect, an absent or reduced recency effect, better recall for visual than auditory presentation, and very poor performance with nonword lists (Hanten & Martin, 2000). In spite of their severe short-term memory deficits, their language comprehension for meaning was found to be maintained, except when processing semantically reversible (e.g., *The cat is chased by the dog*, Caramazza et al., 1981), long and complex (e.g., *Touch the large white circle and the small green square*, Vallar & Baddeley, 1984), and basically lengthy sentences.

Consistent with these findings, McCarthy and Warrington (1987) argued that although patients with short-term memory deficits have difficulty in tasks which require backtracking over spoken speech, they maintain relatively unimpaired online language comprehension skills. They also suggested that when these individuals need to play back what they have heard, the short-term memory system may function as a back-up resource for offline language processing. It has been now suggested that although individuals with low short-term memory spans are less successful in repeating sentences than normal individuals, their comprehension of the sentences is comparable to that of individuals with intact memory function when comprehending sentences even when these sentences have embedded and relative clauses, and passive forms (e.g., Hanten & Martin, 2000; Willis & Gathercole, 2001).

Other functions of the phonological loop related to language have been, as already described above, in first and second language acquisition (e.g., Ellis, 1996; French, 2006; Gathercole & Baddeley, 1989, 1990; Service, 1989), language comprehension (Baddeley & Wilson, 1988; Vallar & Baddeley, 1984, 1987; Vallar & Shallice, 1990), long-term phonological learning (e.g., Baddeley et al., 1988), and recently in representing semantic illusion sentences coherently and in monitoring for details (Büttner, 2012). Semantic illusions consist of two aspects defined as follows: (1) An individual judges a statement (e.g., “Moses took two animals of each kind on the Ark. - True or False?”) to be true when it, in fact, contains a substituted word that makes the statement false; and (2) The individual can be shown to hold the correct

knowledge about which word should have been present in the statement instead of the substitution.

Although it may be of less relevance to language comprehension, the role of the visuo-spatial sketchpad in language comprehension has been reported in processing spatial texts (describing how to go from one part of the city to another) among healthy participants (Pazzaglia & Cornoldi, 1999) and in processing spatially-based syntax (e.g., *The snowman is shorter than the penguin*) among individuals with Williams syndrome (Phillips et al., 2004), that is characteristic of learning difficulties and impaired visuospatial processing (e.g., Jarrold et al., 1999; Vicari & Carlesimo, 2002). Results from Williams syndrome patients show that they did not show impaired comprehension of texts that did not have a spatial constituent (e.g., *Neither the hen nor the duck is standing*), whereas they made more errors when processing texts that contained spatial prepositions (e.g., *The monkey is behind the drum*). Phillips et al. (2004) suggested that it is plausible that the cognitive ability to store and utilise visuospatial information plays a crucial role in spoken language comprehension. Results from healthy participants with two different sizes of spatial working memory (Pazzaglia & Cornoldi, 1999) showed that spatial texts were better recalled among high spatial working memory participants than low spatial working memory participants. Hence, it appears that visuospatial working memory subserved by the visuospatial sketchpad is involved in processing texts that especially contain spatial information.

The third, most complex (Baddeley, 2012) and most important component of working memory (Baddeley, 1996; Dahlin et al., 2009; Gathercole & Pickering, 2001) for a range of cognitive tasks, the central executive, makes a more general contribution to the processing of language for meaning (Gathercole & Baddeley, 1993, p. 222). Of the earliest that explored the relationship between individual differences in working memory (storage and processing functions of WM which are subserved by the central executive and its neural substrates, e.g., D'Esposito et al., 1995; Kane & Engle, 2002) and language comprehension were studies conducted in the early 1980s by Daneman and Carpenter (1980, 1983) and they presented a

measure of working memory capacity that has proved to be a good predictor of language comprehension ability, called the reading span test (RST). In the most common measure of working memory capacity, the RST, participants are required to read a set of novel sentences, ranging from 2 to 6 sets, while memorising the final word of each sentence for later recall. The size of working memory capacity is calculated based on the number of sentence-final words the participants were successfully able to write in the order they appeared. The processes involved in the RST are storing information of words for later recall in a short period of time while tackling a distracting activity, which is comprehension of sentences (i.e., information processing)¹. The idea behind the RST was that this task measured the working memory system that gives rise to complex behaviour better than a simple short-term memory task in which participants are required to remember items without a secondary processing task (e.g., word span) (Unsworth & Engle, 2007).

Daneman and Carpenter (1980) developed other complex span tasks other than the RST, which were the listening span (i.e., instead of reading, the participants heard the sentences) and oral reading span tests (i.e., the participants were required to read aloud the sentences). The participants were given these span tasks and Verbal Scholastic Aptitude Test (VSAT). Daneman and Carpenter (1980) found highly significant correlations between each span measure and reading and listening comprehension measures, as well as scores of VSAT. They postulated that individual differences in WMC are ascribable not to the difference in the amount of available resources, but to the speed and efficiency in executing cognitive activities.

Since Daneman and Carpenter (1980), individual differences in WMC have been explored in various kinds of cognitive tasks such as processing of syntactically complex sentences (King & Just, 1991), where participants with higher reading spans were better than those with low spans in processing (i.e., resolving conflicts in)

¹ It has to be noted that Duff and Logie (2001) argue that very little research measures processing capacity. Processing capacity should be distinguished from storage capacity and is defined in terms of the complexity of relationships that can be processed in parallel (Halford, 1998). Duff and Logie (2001) demonstrated that storage and processing components of the working memory span task seems to require different aspects of the cognitive system (see also Bayliss et al., 2003). Logie and Duff (2007, p.133) further maintained that a combination of at least two different measures of working memory performance (i.e., processing and storage) might offer a more powerful tool than a single memory measure (see also Waters & Caplan, 2003).

sentences with the most complex syntactic structure (e.g., *The reporter the senator attacked admitted the error*). The concept of the central executive role of working memory has been extended and applied in studies of child language acquisition (e.g., Gathercole & Alloway, 2008; Oakhill et al., 1988), second/foreign language learning/acquisition (e.g., Juffs & Harrington, 2011; Kormos & Sáfár, 2008), and in bilingual language processing (e.g., cognitive and linguistic control of their two languages when engaged in a language task, e.g., Bialystok, 2005; Crinion et al., 2006), which are described more in detail in the following sections.

2.4.4 *Executive control*

Human cognition includes everything that entails the exercise of intelligence, for example, such activities as recognising a friend's voice over the telephone, reading a novel, jumping from stone to stone in a creek, explaining an idea to a classmate, remembering the way home from work, and choosing a profession (Osherson, 1995, p. xi). Corr (2010, p. 4) states that *cognition* is the capacity to know and to have knowledge, and this rubric encompasses the structures and processes that support knowing/knowledge. Cognition entails numerous processes: sensory registration, perception, appraisal, decision making, memory, learning, concept formation, perceptual organisations, and language processing is unquestionably one of these cognitive activities. These cognitive activities, such as preparing meals while looking after children or driving vehicles while operating mobile phones (although it is now strictly prohibited around the globe), are often performed either simultaneously or in quick succession (Rubinstein et al., 2001). The explanation behind why such multiple-task performance is achieved almost automatically have been explored and cognitive psychologists put forward that it would be attributable to *executive control* (EC) processes which supervise the selection, initiation, execution, and termination of each task (e.g., Abutalebi et al., 2007; Baddeley, 1986; Duncan, 1986; Norman & Shallice, 1986; Shiffrin & Schneider, 1977; Van Hueven et al., 2008).

Another important component for successfully engaging in everyday behaviours is *attentional control/controlled attention* which seems to play its role to a great degree, particularly in situations where sources of information competing with the task-relevant source need to be inhibited (e.g., Alho et al., 2003; Engle, et al., 1999; Kane & Engle, 2002; Soveri et al., 2011). William James (1890, pp. 403-404) more than a century ago described attention as “[Attention is]...the taking into possession of the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalisation, concentration, of consciousness are of its essence.” Hence, attention is selectivity of processing (Allport, 1993, p. 184). Attentional control, to put it simply, is the capacity to focus and switch attention, whereas executive control is the capacity to monitor and resolve conflicts (e.g., Osaka et al., 2004; Rodriguez-Fornells, et al., 2006; Wang et al., 2009). Perry et al. (2000), in their study with attentional tests on people with Alzheimer’s disease compared with control groups, came to the conclusion that the most sensitive aspect of attentional control is the capacity to resist distraction and rapidly switch attention, and as the disease progresses the ability to sustain and divide attention both decline (Baddeley et al., 2001). Domains where attentional control is recruited are visual (e.g., Baltes & Lindenberger, 1997; Kane et al., 2001), auditory (e.g., Broadbent, 1952, 1954, 1958; Cherry, 1953; Friederici, 2002; Treisman, 1960), and those where multi-tasking needs to be carried out (e.g., Engle, 2002; Pashler, 1992; Watson & Strayer, 2010). Executive control and attentional control are both required for higher order cognitive processing (e.g., Engle & Kane, 2004; Kane & Engle, 2002; Luna & Sweeney, 2004; Nee et al., 2013).

2.4.4.1 Mechanisms of executive control

EC processes (also executive functions, e.g., Miyake et al., 2000), originally conceptualised in the Baddeley and Hitch’s (1974) working memory model as the central executive, function to coordinate dual task performance (e.g., Logie et al., 2004), to inhibit irrelevant information that is distracting attention from the target

information, effectively switch between tasks, and update the contents of immediate memory (e.g., Emerson & Miyake, 2003). Baddeley and Hitch (1974) proposed in their earlier version model of working memory that the central executive, an attention-control system, deals with the regulation of information flow within working memory, the retrieval of information from other memory systems such as long-term memory, and the processing and storage of information (Gathercole & Baddeley, 1993, p. 4). In essence, EC refers to the cognitive processes responsible for high-level action control, planning, inhibition, coordination, and control of action sequences, which are necessary for maintaining a goal and for fulfilling it despite distracting stimuli (Kovács, 2007, p. 310), and that seems to be where the central executive plays a significant role (e.g., Baddeley, 1996).

There are three illustrative theories of EC processes posited by Duncan (1986) (the frontal-lobe executive (FLE) model), Meyer and Kieras (1997a, 1997b, 1999) (the strategic response-deferment (SRD) model) (as cited in Rubinstein et al., 2001), and Engle and Kane (2004) (a two-factor theory of cognitive control).

Observing disorganised behaviours of patients with frontal lobe damage, Duncan (1986) presented the FLE model that has similar presuppositions as in the ATA model. It has been suggested as an approach to understanding executive processes since the system of the central executive has been located in the frontal lobe (e.g. Baddeley, 1996; Braver et al., 2002; Bush et al., 2000; Duncan, 1986; Shallice & Burgess, 1993). Notwithstanding, caution needs to be taken as these biological factors are only a subset of factors influencing performance in executive control tasks (Ilkowska & Engle, 2010, p. 303). The FLE model has three main components: goal lists, means-ends analysis procedures, and action structures. Goal lists, as the name implies, indicate one's prioritised intentions. Means-ends analysis refurbishes the contents and order of goals in working memory, while keeping track of their achievements over time. As a supplement of these functions, the action structures are comprised of a large storeroom of procedural knowledge for goal-directed behaviours incorporated as sets of condition-action production rules (e.g., Allport, 1980). Duncan (1986) claimed that goal lists and means-ends analysis are

implemented primarily in the frontal lobes. Later he and his colleague (Duncan & Owen, 2000) and others (e.g., Derrfus et al., 2004; Nee et al., 2007; Wager et al., 2005) demonstrated that in perception and attention the general executive functions are mediated by a network of not only frontal, but also parietal and sub-cortical structures, which are structurally and functionally connected (Ye & Zhou, 2009a).

The SRD model developed by Meyer and Kieras (1997a, 1997b, 1999) tackles the role of executive control in multiple-task performance. They conceptualised a mental architecture called an executive-process interactive control (EPIC) architecture that integrates various components of the human information-processing system to account for the finding of dual-task costs under simultaneous dual-task performance (Liepelt & Prinz, 2011). The human cognitive system has a limited amount of capacity for information processing and task performance. Principal evidence is derived from dual-task research that demonstrates that simultaneously performing two choice reaction time (RT) tasks considerably slows performance of the second task (Pashler, 1994; Telford, 1931; Welford, 1952). The psychological refractory period (PRP) paradigm, a traditional dual-task paradigm (e.g., Bertelson, 1966; Smith, 1967), has been one of the most important paradigms to visualise and test such processing limitations (Liepelt & Prinz, 2011), in which Meyer and Kieras (1997a, 1997b, 1999) simulated performance in their SRD model. The general finding from early empirical studies on cognitive control was that when the interstimulus interval was very short the response to the first stimulus would be unaffected by the dual-task situation but the response to the second stimulus would be delayed (Cooper, 2010). In the dual-task paradigm where two tasks are given almost simultaneously or consecutively and the first task (T1) receives higher priority than the second task (T2), RTs are measured to estimate the extent to which the two tasks influence each other. In the course of dealing with interference, three sets of production rules in the PRP procedure are presumed. Rule set one carries out operations for T1, that is, selection of T1 reactions. Rule set two deals with operations for T2 and selection of T2 responses. Rule set three, an executive-process rule set, functions as an administrator that programmes these T1 and T2 operations in

order to confirm that task priorities are observed and there are no frictions as for the priorities throughout the operation of limited-capacity perceptual motor components. Under these rules, both T1 and T2 are assumed to be processed without any conflicts while maintaining performance levels.

The general account of theory of executive control (e.g., Botvinick et al., 2001; Engle, 2002; Engle & Kane, 2004; Kane & Engle, 2003; Logan & Gordon, 2001) is that “general cognitive processes that regulate and guide cognitive processes in sensory, memory and motor systems along internal goals, and executive control is composed of at least two components, *conflict monitoring* and *conflict resolution*” (Ye & Zhou, 2009a).

The more recent and possibly the model of executive processes that is as influential as the model of WM by Baddeley and Hitch (1974) is the one proposed by Engle and his colleagues (Engle, 2002, 2010; Engle & Kane, 2004; Engle et al., 1999; Kane & Engle, 2002), who are among the most influential endorsers for developing the idea of a common mechanism behind working memory and inhibition (Birberg Thornberg, 2011, p. 12). They have developed a two-factor theory of cognitive control (Engle & Kane, 2004), in which they argue for a central core of working memory capacity (WMC) that they call executive attention (e.g., Engle, 2002). This core function consists of a mechanism that maintains the goal in active memory and a simultaneous inhibitory function that suppresses prepotent automatic or habitual responses conflicting with behaviours relevant to the current task goal (Engle & Kane, 2004, pp. 185-190).

Traditionally, components in working memory are suggested to be specialised for dealing with specific types of information such as speech (i.e., the phonological loop), visual/spatial (i.e., the visuospatial sketchpad), a multidimensional store that combines information from the subsystems (i.e., the episodic buffer) (Baddeley, 2000), and more recently more specialistic structures that cope with visual and spatial information respectively (Logie, 2003). Engle and Kane (2004), on the contrary, have maintained that they regard working memory as a system consisting of *domain-specific* memory stores with associated rehearsal procedures and *domain-*

general executive attention. An emphasis was put on the interaction of attentional and memorial processes in the working memory system, and this interaction between attention and memory was considered to be a primary determinant of broad cognitive ability. They also took Cowan's (1995, 1999) approach into consideration that the coding, rehearsal, and maintenance processes of immediate memory work on activated long-term memory (LTM) traces, rather than retaining separate representations in domain-specific storage structures (Engle & Kane, 2004, p. 147).

Through correlational, factor, latent variable, and structural equation modelling analyses between short-term memory (STM) tasks such as digit, letter, and word span tasks, complex WMC measures such as operation span, reading span, and counting span tasks, general fluid intelligence tests such as Raven's Progressive Matrices test, and Cattell Culture Fair Test (e.g., Conway et al., 2002; Duncan et al., 1995), and visuospatial tasks, Engle and Kane (2004) have found that measures of STM are correlated poorly with general measures of intelligence (e.g., Raven's Progressive Matrices test, and Cattell Culture Fair Test), however, measures of WMC show significantly high correlations with a wide range of such general cognitive measures. Results from the studies also demonstrate that the construct indicated by WMC tasks (see note 1 on p. 99) is strongly linked to general fluid intelligence above and beyond what these tasks share with simple STM span tasks. Their two-factor model of WMC is of significant relevance to the current dissertation in that it proposes that executive attention is important for maintaining information in active memory and secondly it is important in the resolution of conflict resulting from competition between task-appropriate responses and prepotent but inappropriate responses (Engle & Kane, 2004, p. 193), which seems similar to the situation where bilingual listeners need to maintain attention to one language and resolve conflicts from another. The advantage of their executive attention theory is that it is flexible enough to allow individuals with high WMC to use their capability in a number of ways, depending on what is called for by successful performance on the task at hand (Engle, 2010, p. S24). The concept of WMC has been integrated into recent research on bilingual language production and comprehension, and cognitive development

(e.g., Bialystok, 1999, 2001, 2005, 2009; Bialystok et al., 2004; 2008; Craik et al., 2010; Emmorey et al., 2008; Kovács, 2007).

The following subsections observe mechanisms of executive control and attentional control in language processing among bilinguals respectively.

2.4.4.2 *Executive control in language processing*

This section overviews how executive control plays its role in language comprehension within and across languages.

In a daily communication, listeners need to choose/control what they believe from what they hear, i.e., judging whether a sentence is consistent with their world knowledge (Ye & Zhou, 2009a). Bilingual listeners need a control mechanism to inhibit interference from the language not in use at the moment (Green, 1998). In the real-life communication environment, the rich source of information and the large number of behavioural options force great potentials of interference and consequently, require attentional control and voluntary coordination, which are taken care of by executive control (Ye & Zhou, 2009a). The mechanisms of executive control, as described above, can regulate and guide cognitive processes in sensory, memory and motor systems along internal goals (Miller & Cohen, 2001; Miyake et al., 2000; Ye & Zhou, 2009a), responsible for high-level action control, planning, inhibition, coordination, and control of action sequences, which are necessary for maintaining a goal and for fulfilling it despite distracting stimuli (Kovács, 2007, p. 310). The listener may use these executive control functions to determine among competing interpretations in accordance with the current communication goal (e.g., to grasp what the speaker really says and ignore what one already knows) (Ye & Zhou, 2008, 2009a).

Working memory is critical for making sense of anything that unfolds over time, for that always requires holding in mind what happened earlier and relating that to what comes later, hence, it is necessary for making sense of written or spoken language whether it is a sentence, a paragraph, or a longer speech (Diamond, 2013,

pp. 142-143). The role of executive control subserved by working memory has been explored using written paragraphs which have ambiguous relations between sentences or words (e.g., Daneman & Carpenter, 1983; MacDonald et al., 1992; May et al., 1999), and sentences which have irrelevant endings, i.e., garden-path sentences (e.g., Frazier & Rayner, 1982), and also at the auditory sentence level (e.g., Felser et al., 2003). Results from these behavioural studies and those from cognitive neuroscience (e.g., Novick et al., 2005; Mason et al., 2003) indicate that semantic and syntactic ambiguity resolution is more efficiently achieved by high-WMC individuals and subserved by the same networking brain structure of executive control.

Ye and Zhou (2009b) investigated to what extent the neural correlates of executive control processes in processing sentences are comparable to those in perception and attention which involve conflict resolution. In the sentence comprehension task, the participants were asked to read a sentence word by word, and judge whether the sentence was semantically consistent with the previous one. The experimental sentences were presented in four conditions: (1) the active plausible (e.g., *The policeman kept the thief in the police station*), (2) the active implausible (e.g., *The thief kept the policeman in the police station*), (3) the passive plausible (e.g., *The thief was kept by the police in the policeman station*), and (4) the passive implausible (e.g., *The policeman was kept by the thief in the police station*). Each of these sentences was followed by a probe sentence whose syntactic structure was Subject-Verb-Object. A half of the probe sentences were semantically consistent with the experimental ones and another half were not. The semantically inconsistent probe sentences were generated by reversing thematic roles or replacing verbs in the corresponding experimental sentences. WMC tasks to estimate executive control were the flanker task and the colour-word Stroop task (e.g., Miyake et al., 2000; Nee et al., 2007). In the colour-word Stroop task, participants had to name the ink colour of a colour word, the meaning of which was either consistent (e.g., word RED in red ink) or inconsistent (e.g., word RED in green ink) with the ink colour. Ye and Zhou (2009b) predicted that a network activated for processing implausible sentences in

contrast to plausible ones should be also activated for the incongruent \times congruent contrast in the flanker and Stroop tasks, that is, if executive functions are common to the conflict control across domains, the neural correlates of control processes in the above three tasks may overlap in corresponding brain regions. Their findings support the hypothesis. They found common brain regions (dorsal medial prefrontal cortex (PFC), ventral lateral PFC, and inferior parietal cortex) recruited for conflict resolution in both the sentence comprehension and WMC tasks. Hence, domain-general mechanisms of executive control (assessed by the flanker and Stroop tasks) are employed to cope with conflicts occurring in sentence comprehension.

Bilinguals are continuously faced with the challenge of controlling their two languages during communication to avoid interference from the non-target language (Hernandez et al., 2005; Meuter, 2005; Rodriguez-Fornells, et al., 2006), where mechanisms of effective interference prevention would be required (Penfield & Roberts, 1959). It appears that bilinguals tackle interference in language processing by employing brain areas responsible for general executive control processing (e.g., Abutalebi et al., 2000; Crinion et al., 2006; Jackson et al., 2001; Rodriguez-Fornells, et al., 2006; Rodriguez-Fornells, et al., 2002; Rodriguez-Fornells, et al., 2005). To reiterate, situations where interference is involved are where executive control processes are most required (Kane & Engle, 2002, p. 638). Brain areas which have been found to subserve executive control in bilingual language processing are the left caudate (e.g., Crinion et al., 2006), anterior cingulate cortex (ACC) (e.g., Abutalebi et al., 2007; Rodriguez-Fornells et al., 2006; Van Hueven et al., 2008), dorsolateral prefrontal cortex (DLPFC) (e.g., Holtzheimer et al., 2005; Van Hueven et al., 2008) and superior parietal lobule (SPL) (e.g., Abutalebi et al., 2000; Hernandez, 2009). These areas also have been identified and found to play individual roles in general executive control (e.g., Collette & Van der Linden, 2002; D'Esposito et al., 1995; Osaka & Osaka, 2007). The mechanisms of resolution of language interference (i.e., language control) are discussed in more detail in the next section, and here recent studies on the role of executive control in bilingual language comprehension of words at the auditory level are presented.

Employing a relatively larger linguistic unit, i.e., words, and the visual-world paradigm, Blumenfeld and Marian (2011) sought to investigate bilinguals' (English-Spanish) inhibitory control in processing auditorily presented L1 words in the presence of competing visual information from high phonologically similar L1 words (e.g., target: *cab*, competitor: *cat*), and those of higher frequency than target words to maximise involvement of cognitive control processing. Two types of trials were presented: Word Recognition/Eye-tracking and Priming Probe trials. Priming Probe always followed Word Recognition/Eye-tracking trials. In Word Recognition/Eye-tracking trials, four pictures, one of which was the target (e.g., *plum*), another competitor (e.g., *plug*), the rest neutral (e.g., *ant* and *hoover*), were presented. The participants were instructed to press one of four keys that was located in the corresponding location of the target as they heard the word and their eye-movements were recorded. Priming Probe trial followed, where there were one grey asterisk that appeared in the location previously filled by a picture of competitor, control, or target word, and three black asterisks. In this trial, the participants had to press a key whose position corresponded to the location of the grey asterisk. Three types of priming probe trials: (1) control probe trials, (2) competitor probe trials, and (3) target probe trials were employed to ensure that inhibition of preceding lexical competitors was reliably indexed. On each of these trials, the grey asterisk appeared in the same location as a control, competitor, and target picture on the preceding Word Recognition trial. The participants also took the Stroop task (Stroop, 1935) that had arrow direction and arrow location creating the Stroop-type effect (Liu et al., 2004) to estimate the participants' inhibitory control capacity.

The bilingual participants and their monolingual peers were found to perform equally in the eye-tracking tasks indicating that phonologically similar competitors cast equivalent influence on both groups' identification of target words. Their accuracy was lower and their response was slower to identify the target words when confronted with the competitors than when they were not present. In the priming probe trial, both groups equally accurately located the position of the target grey asterisk. As expected, the participants responded quicker when the grey asterisk

appeared in the same location previously filled by the target picture than when filled by the control picture. In the Stroop task, the bilingual participants were more accurate than the monolinguals, but their response times were comparable. Although marginal, a smaller Stroop effect (as measured by reaction times on incongruent trials minus reaction times on congruent trials) was found in bilinguals indicating a bilingual advantage in non-linguistic inhibitory control. The relationship between the Stroop effect and efficiency in linguistic inhibition was examined and a negative correlation between Stroop inhibition and competitor priming was found in bilinguals, implying that more efficient Stroop inhibition is associated with less inhibition of the linguistic competitor. Another negative correlation was found between the Stroop effect and target priming, suggesting that more efficiency in resolving conflicts in the Stroop task is associated with more target activation. These tendencies were not found in monolinguals. Blumenfeld and Marian (2011) argue that bilinguals maintain a stronger bond between non-linguistic and linguistic inhibition than monolinguals.

Another set of correlational analyses were conducted to associate the degree of competitor activation in picture identification with measures of subsequent inhibition, by comparing competitor activation to negative priming effects and to non-linguistic Stroop effects. Competitor activation was analysed during the 200-933 ms competition window. A positive correlation was found between competitor activation and negative priming between 433 ms and 600 ms post-stimulus onset among monolinguals, meaning that the less competitor activation was available, the stronger the negative priming effect. Among bilinguals, between 666.7 and 833.3 ms post-stimulus onset, a negative correlation was found between competitor activation and negative priming, implying that the greater the lexical activation during this time-window, the stronger the negative priming effect bilinguals received.

Blumenfeld and Marian's (2011) eye-tracking and correlation data indicate that there was no difference in the speed of competition resolution from phonologically similar words between monolinguals and bilinguals, and that non-linguistic inhibition, i.e., Stroop inhibition, seems to be related to the ability to resolve

competition among not monolinguals but bilinguals. Their findings that bilinguals were earlier to return to a baseline state compared to monolinguals after successful inhibition of the preceding competitor word further suggest that an ability to *disengage* more quickly from inhibiting irrelevant information may be especially important in bilingual language processing, where an irrelevant language may become relevant at any point in time.

Mercier, Pivneva, and Titone (2014) furthered Blumenfeld and Marian's (2011) study with the same visual-world paradigm and a set of inhibitory control tasks (the non-verbal version Simon task (Blumenfeld & Marian, 2007)), two Stroop tasks (Liu et al., 2004; Stroop, 1935), and an anti-saccade task (Hallet, 1978)) to investigate how individual differences in cognitive and oculomotor inhibitory control modulate within- and cross-language competition (which was not studied in Blumenfeld & Marian's (2011) study) among bilinguals with varying degrees of exposure to L2 English, which was shown to be significantly correlated with L2 proficiency). Their results showed that regardless of the amount of exposure to L2 the bilingual participants demonstrated less within-language competition which was associated with their increased cognitive inhibitory control. Among bilinguals with less L2 exposure, less cross-language competition was found, whereas bilinguals with high L2 exposure were found to fixate more on cross-language competitors. In the similar vein, regardless of the amount of L2 exposure, increased oculomotor inhibitory control assessed by the anti-saccade task was found to be related to less within-language competition. Bilinguals with less L2 exposure, who also showed poor oculomotor inhibitory control, demonstrated the greater increase in cross-language competition, whereas less-L2-exposure bilinguals with good cognitive inhibitory control did not show such competition.

Analyses of the relationship between bilingual word recognition and inhibitory control revealed that higher cognitive inhibitory control was related to both less within- and cross-language competition. Hence, non-verbal cognitive inhibition seems to be important for the resolution of lexical competition to the extent that it is profound enough to influence comprehension. The role of oculomotor inhibitory

control was manifest among low-L2-exposure participants especially when they were presented with both within- and cross-language competitors, where they presumably had to exert more control over their eye movements to redirect their attention to the target pictures, thereby slowing their selection of the relevant picture. Under this cognitively demanding situation or in populations whose inhibitory control is undermined, different levels of inhibitory control may be employed depending on the specific task demands. Since the bilingual advantage has been found consistently in more cognitively demanding tasks (e.g., the Simon task, flanker task, Raven's Matrices) (e.g., Bialystok et al., 2008; Bialystok et al., 2004; Emmorey et al., 2008), Mercier et al. (2014) suggest that it be necessary to employ different and cognitively demanding language processing situations to investigate the role of inhibitory control in bilingual language processing.

2.4.4.3 *Mechanisms of attentional control*

Differences between executive control and attentional control lie in the capacities to monitor and resolve conflicts (*executive control*) and to focus and switch attention (*attentional control*) (e.g., Osaka et al., 2004; Rodriguez-Fornellss, et al., 2006; Wang et al., 2009). Attentional control is one of the roles subserved by the central executive other than the control of the slave subsystems and the manipulation of information within working memory (e.g., Baddeley, 2001; Repovš & Baddeley, 2006). The core of individual differences in measures of WMC is the ability to control attention to maintain representations most relevant to the task at hand in active memory or most easily retrievable from inactive memory and that this comes into play most directly under conditions of interference from competing representations (Engle, 2010, p. S21). The central function of selective attention is to prevent actions from being inappropriately driven by the most perceptually salient information (Diamond, 1990). Acting towards the task goal requires the role of mental set in illustrating task demands differentiating task-appropriate and task-inappropriate information (e.g., Norman & Shallice, 1986; Rogers & Monsell, 1995).

One of the most influential models of attentional control, which sought to substitute the idea of homunculus in Baddeley's working memory model (1986), is the attention-to-action (ATA) model proposed by Norman and Shallice (1986).

The ATA model proposed by Norman and Shallice (1986) has three subcomponents: action schemas, contention scheduling, and a supervisory attentional system (SAS), which was first developed by the same authors in 1980 and which Baddeley (1986) proposed to adopt as a working hypothesis for the central executive. Action schemas are specialised routines for doing individual tasks which entail well-learned perceptual-motor and cognitive skills. Each of action schemas has a current degree of activation that may be increased by either specific perceptual trigger stimuli or outputs from other relevant schemas. Occasionally, different trigger stimuli may activate multiple schemas, that is, doing several tasks simultaneously, bringing about conflicts that can lead to errors if they call for mutually exclusive reactions (e.g., taking notes and talking on a phone at the same time). In order to resolve these conflicts, contention scheduling is adopted in the ATA model. With an interconnected structure of lateral inhibitory connections among action schemas whose response outputs would interfere with each other, contention scheduling functions rapidly, automatically, and unconsciously. Through this structure, an action schema (e.g., one for note-taking) that has relatively high current activation may prevent the activation of other potentially conflicting schemas (e.g., one for phone talking). Task priorities and environmental cues are assessed without explicit top-down executive control. Despite that, this may not be sufficient when dealing with new tasks, unusual task combinations, or complex behaviours. Here, the SAS plays its role and guides behaviour slowly, flexibly, and consciously in a top-down fashion. It aids in organising complicated actions and performing unfamiliar tasks by selectively activating or suppressing particular action schemas, replacing the cruder bottom-up influences of contention scheduling and better accommodating one's overall capacities and goals. In some situations, the limited capacity SAS intervenes by redirecting and giving schemas appropriate priorities, inhibiting those incompatible with a current goal (Ilkowska & Engle, 2010, p. 297).

A large and consistent body of research demonstrates that the ability to “control attention” (also referred to as “controlled attention” (e.g., Engle et al., 1999; Kane et al., 2001), and “attentional control” (e.g., Bialystok, 2009; Shtyrov, 2010; Soveri et al., 2011)), especially in the presence of competing stimuli, is a major determiner of an individual’s performance on complex working memory tasks (e.g., Engle, 2002; Kane et al., 2001). Consistent views have been obtained from computational modelling views of working memory (Anderson, 1983; O’Reilly et al., 1999), as well as neurobiological theories (e.g., Braver & Cohen, 2000; Miller & Cohen, 2001) where they refer to the cognitive capacity as “the ability to select a weaker, task-relevant response (or source of information) in the face of competition from an otherwise stronger, but task irrelevant one” (Miller & Cohen, 2001, p. 170).

The critical element of complex WMC span tasks for higher-order cognition and general fluid abilities, whether spatial or verbal, is the domain-general capacity to control attention (e.g., Engle & Kane, 2004, p. 180; Engle et al., 1999). Attentional control mechanism is analogous to the concept of limited-capacity central executive in the working memory models (e.g., Baddeley & Hitch, 1974; Norman & Shallice, 1986; more recently the control network proposed by Schneider & Chein, 2003, which integrates a control network at the neural level consisting of multiple brain areas that play a crucial role in controlling a set of cognitive functioning). The view of WMC as a control of attention (Ilkowska & Engle, 2010, p. 297) is suggested to integrate attentional control with memory (Engle & Kane, 2004; Kane et al., 2001; Kane & Engle, 2002). Ilkowska and Engle (2010) are in agreement with Unsworth and Engle’s (2007) suggestion that individual differences in WMC are rooted in two memory components: a dynamic attention component (primary memory) and a probabilistic cue-dependent search component (secondary memory). Since individuals with low WMC show a poorer execution of these two processes, both of these components (primary memory and secondary memory) play a crucial role in active maintenance and retrieval of goal-related information (Ilkowska & Engle, 2010, p. 297). Importantly, if differences emerge between low- and high-WMC individuals on the performance of tasks that require responses counter to strongly

established (i.e., automatic) stimulus-response connections, WMC differences are to be measurable in “attention control” tasks that are further removed from a memory context (Engle & Kane, 2004, p. 184). Attentional control is important to strengthening the activation of representations critical (relevant) to the current task but also important to the discarding or inhibition of (task-irrelevant) representations that would interrupt the task (Engle, 2010, p. S22).

Evidence for the attentional control capability of WMC, since it is domain-general (e.g., Engle, 2010; Engle et al., 1999), comes from both verbal and non-verbal paradigms. Here, results from non-verbal tasks are presented. One non-verbal paradigm that has been employed to explore the attentional control is the antisaccade task (Hallet, 1987). In their version of antisaccade task, Unsworth, Schrock, and Engle (2004) showed their participants two boxes, one of which flashed at some point, and the participants were asked to fixate their eyes on the flashing box (prosaccade condition) or the other box (antisaccade condition) as soon as one of the boxes flashed. Their eye movements (fixation and saccades) were recorded. Prosaccade trials simply require looking toward the flashing box, and this response is thought to rely on automatic attentional capture and should not require the recruitment of attentional control. Antisaccade trials, on the contrary, require not only the inhibition of a prepotent response but also the planning and execution of a voluntary saccade in the opposite direction. Antisaccades are essentially voluntary saccades generated via top-down control and thus require a degree of attentional control, that is not apparent in the relatively automatic prosaccades (Kane et al., 2001). Hence, antisaccades but not prosaccades should require attentional control, and thus individual differences in WM span should be apparent only in antisaccade trials (Unsworth et al., 2004). As they predicted, although no differences were found between low- and high-WMC participants in the prosaccade condition, low-WMC participants made considerably more errors in the antisaccade condition than high-WMC participants, suggesting that they were more vulnerable to the condition where distractors have to be suppressed.

Table 2.2. *Congruent and Incongruent Conditions in the Attention Network Task*

		Congruency	
		Congruent	Incongruent
Response direction	Left	← ← ← ← ←	→ → ← → →
	Right	→ → → → →	← ← → ← ←

Another approach to the study of attentional control is the attention network task (ANT) (Fan et al., 2002). In this task, participants are shown five arrows, one of which at the centre is pointing to the same or opposite direction to the other arrows (see Table 2.2), and are required to indicate the direction of the arrow. The target stimulus was preceded by cues of either of three kinds (alerting, orienting, and executive attention), to examine the three different aspects of attention, thereby demonstrating the capacity to withstand attention seizure by the environmental cues and focus attention to the task-relevant stimuli. The alerting cue was indicated with an asterisk shown at the centre of the screen, which was compatible with the location of the target. The orienting cue was shown with two asterisks, one of which shown above and the other below the centre. The executive attention cue was presented with an asterisk shown either above or below the centre to distract the participant's attention to the centre of the screen. With low- and high-WMC participants screened on the operation span (OSPAN) task (Turner & Engle, 1989), Redick and Engle (2006) examined their performance on the ANT. They found supporting evidence to the view that individual differences in WMC reflect variation in the ability to control attention. As expected, low-WMC participants showed much poorer performance on the test of executive attention than did high-WMC participants.

Executive attention is especially important for maintaining access to stimulus, context, and goal information in the face of interference or other sources of conflict (Engle & Kane, 2004, p. 149), as can be seen in attentional control tasks described above. The next section observes the role of attentional control in language

processing, where both internal and external sources of conflict may well be involved.

2.4.4.4 *Attentional control in language processing*

The capacity to direct and focus attention is perhaps the most crucial feature of working memory, and, although it is suggested to have a limited capacity, simultaneous performance of two complex tasks may be possible under highly constrained conditions (Baddeley, 2007, p. 124). For instance, Allport, Antonis, and Reynolds (1972) showed that it is possible for individuals to divide their attention to do two unrelated and concurrent tasks (e.g., repeating back continuous speech while remembering visually presented words or pictures or shadowing auditory prose while playing piano music from a score: the latter was performed with little or no loss of efficiency in either task), and perform these as well as when attention division was not required. The findings led them to suggest the multi-channel hypothesis that the same tasks paired respectively with another task requiring none of the same basic processors can in principle be performed in parallel with the latter without mutual interference (Allport et al., 1972), moderately challenging the single channel hypothesis (e.g., Kahneman, 1970) (although they admit that the single-channel operation can occur when individuals need to concentrate on a particular task where specialised processors are required). Evidence of attentional control has been also reported in studies with chess players who were asked to memorise chess positions or choosing the next move while uttering an irrelevant word (articulatory suppression task), however, they showed intact memory for chess positions, although their recall was substantially impaired when paired with visual (spatial tapping) and central executive tasks (random generation of sequences of numbers (e.g., Bradley et al., 1987; Robbins et al., 1996; Saariluoma, 1992), suggesting no verbal contribution, a concurrent attentionally demanding task such as the central executive task impairs positional memory and casts a greater effect on move selection (Baddeley & Hitch, 2007, p. 7).

“Supertaskers” (e.g., Watson & Strayer, 2010) have been found to be significantly better at measures of everyday task (e.g., driving: following distance and braking performance), maths, and OSPAN, not only when they performed these tasks individually, but also when they were given a dual task where they had to do driving while concurrently doing an auditory version of the OSPAN task. Although small in number ($N = 5$), Watson and Strayer (2010) found that there were individuals whose performance showed no decline when moving from single to dual task across all the dependent measures, although the rest of 97% demonstrated substantial performance costs. As the frequency of supertaskers was significantly greater than chance, the authors suggest that an individual-difference variable underlying this effect is associated with differences in executive attention (e.g., Engle, 2002; Engle & Kane, 2004; Kane & Engle, 2002). Thus, significantly high WMC of the supertaskers helped them divide their attention to two tasks (both of which entail complex cognitive processes) simultaneously and reduce interference from another cognitively demanding task to a minimal degree while concurrently performing both tasks with no tractable performance declines.

Effective switching from one task to another requires executive processes that are responsible for controlling and coordinating the execution of goal-directed behaviour (Lezak, 1995). Such processes are recruited in situations such as when there are multiple task goals, and attention must be shifted back and forth between the tasks based on the current task goal, and when there are two competing alternatives in some task, and the interference between the two must be resolved so that attention is maintained to one instead of the other (Sylvester et al., 2003). Task switching is characterised by its “cost” produced when switching from one task to another, resulting in slower speed or lower accuracy after switching (e.g., Baddeley et al., 2001; Monsell, 2003). Kane et al. (2001) found in the antisaccade task that low-WMC participants’ performance was slower and less accurate than high-WMC participants, and furthermore that low-WMC participants’ performance was poorer when they had to switch from more demanding antisaccade to less demanding, rather automatic, prosaccade conditions, suggesting that it is more difficult for low-WMC

participants to shift instructional set from a controlled task to an automatic task. In a similar vein, Meuter and Allport (1999) found a counterintuitive switching cost in bilinguals, that is, when they were asked to perform the picture naming task while cued to switch between languages, larger switch costs were found not when switching from L1 to L2, but when switching from L2 to L1. This is what Allport et al. (1994) called task-set inertia, a kind of proactive interference (Kane et al., 2001) in which a non-dominant response mapping (L2 in their case) puts a stronger set that is more difficult to conquer than is the set for a dominant response (L1). This phenomenon has been also found in a word reading task (e.g., Macizo et al., 2012).

In language comprehension, the role of attentional control, the ability to inhibit or suppress unwanted information (Barrett et al., 2004) especially when there is interference (e.g., Engle & Kane, 2004) was investigated in a study by Gernsbacher, Varner, and Faust (1990) where the participants were instructed to judge whether a word was related to a previously shown sentence (Experiment 4). For example, in the congruent condition the participants were shown a sentence word by word, e.g., “*She liked the rose,*” a test word “*flower*” immediately or 750 ms after the sentence, then they were instructed to respond whether the test word was related to the final word of the sentence. In the incongruent condition, the sentence stimulus was, e.g., “*He dug with the spade,*” and the test word was “*ace.*” A sentence with the last word replaced by “*shovel,*” a semantically explicit word, was also shown to examine how activated the inappropriate meaning of the ambiguous word was, that is, if the participants were slower to reject *ace* after the sentence with “*spade,*” it would suggest that they were interfered with by the contextually irrelevant meaning. The participants were divided based on their general comprehension skill assessed by a Multi-Media Comprehension Battery (Gernsbacher & Varner, 1988) where reading and listening skills were examined, into skilled comprehenders and less skilled comprehenders. As a result, more interference from the semantically irrelevant word was experienced by less skilled comprehenders than skilled comprehenders. Skilled comprehenders showed less interference in the delayed condition than the immediate condition, suggesting that skilled comprehenders have the capacity to suppress irrelevant

information more rapidly (efficiently) than less skilled comprehenders, who may have less rapid suppression mechanism.

Sanchez and Wiley (2006) investigated the role of WMC in the seductive details effect (Garner et al., 1992), that is, illustrations can impede comprehension of a text if they are irrelevant to understanding the text. The participants were given a text in Web page format in three conditions: (1) non-illustrated, (2) illustrated with 12 images and (3) illustrated with 12 seductive images. The text was about what causes ice ages. Illustrations relevant to the topic were those of the sea level differences between the great ice age and present, and carbon dioxide cycle, whereas seductive illustrations were those of flowers and a river of snow. The eye-tracking paradigm was employed to evaluate the reading patterns between low- and high-WMC participants. The participants' WMC was estimated by the OSPAN and RST. Results showed that low-WMC participants indicated a larger seductive details effect on text comprehension, and their attention was more often and longer drawn to the seductive illustrations than high-WMC participants. On the contrary, fewer eye fixations on seductive illustrations were observed among high-WMC participants, which indicates their more efficient inhibition of irrelevant information, leading to their better comprehension.

Further evidence is drawn from a neuroimaging study by Prat, Keller, and Just (2007) in which the participants were asked to read sentences of varying degrees of lexical frequency or syntactic complexity while their brain activity was recorded by fMRI. The authors aimed to uncover the relationship between characteristics of brain activation and the behavioural characteristics associated with high- and low-WMC readers. As anticipated, greater efficiency in reading comprehension as indexed by less brain activation but higher comprehension was observed in high-WMC participants. They were also found to be more adaptable to changing task demands, i.e., lexical complexity. Greater synchronisation of brain networks for reading comprehension was found in high-WMC participants and it remained constant in spite of increasing lexical and syntactic complexity.

For bilinguals to succeed in producing and comprehending an intended language, they are required to cope with competing phonological, syntactic, and prosodic systems, as well as distinct mappings of orthography to phonology (Abutalebi & Green, 2007). Nevertheless, it has been found that bilingual speakers experience interference and competition between their languages while being engaged in both language production and comprehension (e.g., Abutalebi et al., 2007, 2008; Rodriguez-Fornells et al., 2002, 2005; Wang et al., 2007, 2008), where they must have effective neural mechanisms to control and regulate the activation of their two language systems (Abutalebi & Green, 2007; Green, 1986, 1998; Wang et al., 2007, 2008). It has been also discovered that the brain's executive control network not only subserves language control in bilingual speech production, but also in bilingual auditory comprehension (e.g., Abutalebi et al., 2007). Since bilingual language control and executive attention are closely related and of great relevance and significance to the current investigation of the mechanism of bilingual speech comprehension, they are discussed thoroughly in the next section, and accordingly, attentional control in the auditory domain in relation to bilingual speech comprehension follows.

2.5 Language control

Language control (LC) is a crucial aspect of the bilingual language system (Abutalebi, 2008). During both language comprehension and language production, both of a bilingual's languages are activated to a certain degree, even when attention is directed to only one of them (e.g., Costa et al., 1999; Schwartz et al., 2007; Thierry & Wu, 2007), and it appears to be impossible to deactivate the unattended language (Kroll et al., 2012). The LC mechanisms recruited by bilinguals are beyond those required in one language by monolinguals, in addition to knowledge and use of two sets of phonologies, lexicons, grammars, etc. (Golestani, 2014), hence the bilingual linguistic system is noisier (i.e., both linguistic subsystems are activated) than that of monolinguals (de Groot, 2011, p. 279). Thus, LC is crucial and required to survive

the linguistically noisy tangle in the bilingual's mind and select the appropriate language and inhibit the lexicon of the non-target language (e.g., Abutalebi et al., 2008; Christoffels et al., 2007; Green, 1986, 1998). Recently, it has been revealed that controlling what language to speak and perceive enhances a general cognitive control mechanism (e.g., Bialystok, 1999, 2009; Emmorey et al., 2008; Kroll et al., 2012).

Since both of a bilingual's languages are simultaneously active to a certain degree (e.g., Kroll et al., 2012; Thierry & Wu, 2007), not only the LC mechanism that enables her to perform in one language, but also the ability to switch between her two languages have to be readily available (e.g., Green, 1998; Muysken, 2000). Results from neuroimaging studies (e.g., ERPs) demonstrate that language switching is carried out by inhibiting the non-target language, whether L1 or L2, and more inhibition is required when switching from L2 to L1 than vice versa, resulting in asymmetrical switch costs (e.g., Verhoef et al., 2009). The major determinants of the language switch cost are presumed to derive from the language just used rather than from the language to be switched to (e.g., Meuter, 2009, p. 33; Wylie & Allport, 2000). Inhibition has been found to be not necessary, but helpful as a modulator for efficient language switching (Verhoef et al., 2009).

In this section, earlier studies on language control, and cognitive mechanisms of bilingual language control and language switching will be presented accompanied by findings from psycholinguistic and neuroimaging studies that have contributed to the understanding of how the bilingual's language control and language switching are represented in the brain.

2.5.1 How language is selected and inhibited: Early language switching studies

Studies on bilingual language control dates back to the 1960s when the language-switching paradigm was used to investigate both production and comprehension (e.g., Kolers, 1966; Macnamara, 1967; Macnamara et al., 1968). In studies of language control in comprehension (e.g. Kolers, 1966; Macnamara, 1967), the participants were visually presented with either monolingual (non-switch trials) or

code-switched complete sentences (or passages) (i.e., sentences in a base language with words or phrases in the other language) to investigate what would happen in the bilingual's mind in both of these conditions.

In Kolers' (1966) study, in the code-switched passages, alternate sentences were in English or French; in half of the passages the first sentence in English and in the other half the first sentence in French. Linguistically mixed passages were included, where words were randomly in English or French, half of the passages favouring English word-order and the other half favouring French. An example of a linguistically mixed passage with a predominantly English word-order is:

His horse, followed de deux bassets, faisait la terre résonner under its even tread. Des gouttes de verglas stuck to his manteau. Une violente brise was blowing. One side de l'horizon lighted up, and dans la blancheur of the early morning light, il aperçut rabbits hopping at the bord de leurs terriers. Tout de suite the two hounds rushed sur eux and, vivement throwing them back and forth, brisaient leur échine. Bientôt il came to a forest. In a tree, au bout of a branch, un wood grouse, numbed par le froid, dormait with its head under l'aile. D'un revers of his sword he cut off its deux pattes, et continua sa route sans picking it up. Trois heures après, il was on the top of a montagne.

The participants (English-dominant English-French, and French-dominant French-English bilinguals) were given three seconds to read each line and two minutes to answer comprehension questions. As a result, English-French bilinguals scored higher on mixed passages which favoured the English word-order, and French-English bilinguals also scored higher on mixed passages which favoured the French word-order, suggesting that the bilinguals comprehend passages better when the word-order is that of their native language. In the following experiment, Kolers (1966) asked the participants to read aloud monolingual and mixed passages to estimate the mean time-cost (costs of switching) for a switch of spoken language.

However, his measure did not in fact distinguish between the direction of switch from L1 or L2 as opposed to from L2 to L1 (Meuter & Allport, 1999).

Macnamara and Kushnir (1971) examined “the input switch” by comparing times for the processing of monolingual materials with times for the processing of bilingual ones. They employed full English sentences and predicted that it would take longer to process mixed or bilingual materials than monolingual ones. The participants were asked to (1) read silently monolingual and bilingual paragraphs and reading times, (2) read single monolingual and bilingual sentences and judge the factuality of each sentence, and (3) listen to monolingual and bilingual sentences and judge their factuality. In each condition, times spent on processing each language condition (i.e., costs of language switching) were compared.

In their first experiment, four paragraphs with basically the same message, similar to the ones used by Kolers (1966), one in English, one in French, one with French words and phrases incorporated in the English paragraph, and one with English words incorporated in the French paragraph, were prepared and the participants read them silently. Macnamara and Kushnir (1971) calculated a mean time per syllable on the monolingual paragraphs and estimated a composite reading time for the bilingual paragraphs. The composite reading time was subtracted from a reading time for a bilingual paragraph and the resulting difference scores were analysed. There were thirty-three language switches in each bilingual paragraph. A mean time per language switch was calculated to be 170 ms, which was much smaller than that of 300 to 500 ms reported by Kolers (1966), perhaps because Macnamara and Kushnir’s (1971) measured language switching solely in input. Although they did not report reading time differences between different bilingual groups (English-French and French-English bilinguals), they found that the language switching (i.e., reading paragraphs with mixed languages) took the participants a noticeable amount of time.

In their second experiment, Macnamara and Kushnir (1971) prepared short monolingual and bilingual sentences with a different number of language switches from one to three. For example, a mixed sentence with three language switches was

such as *Les oiseaux* have *deux* wings, where switches occurred between *oiseaux* and have, between have and *deux*, and *deux* and wings. The participants read each of these sentences silently and judged it true or false. The response time for each sentence was recorded. Response times were found to be faster for sentences in which the participants' dominant language was used, hence, faster response times for the English sentences by English L1 participants and faster response times for the French sentences by French L1 participants. No differences between the two language groups were observed in response times for the mixed language sentences with language switches. It took again longer to respond to mixed language sentences than to monolingual ones. Increased response times were observed as the number of language switches increased.

Their third experiment investigated whether response times would be faster if the bilingual participants became aware of the order of language switches. There were two blocks of trials, each of which contained twelve sentences, six in English and another six with a single language switch. In one block, the English and mixed sentences were presented in an alternating order so that the participants could foresee which sentences would include a language switch, whereas in the other block, these sentences were presented at random so that the participants would not be able to predict an occurrence of a language switch. Contrary to their expectation, Macnamara and Kushnir (1971) found that the participants were slowed down on the trials with the fixed order of language switches, implying that the participants' attempt to be vigilant with both language systems simultaneously ended up making the task more difficult.

Finally, their fourth experiment sought to confirm if the smaller switching times observed in their previous studies (written language processing) compared to those found by Kollers (1966) (reading aloud) would have been due to the types of speech processing, that is, whether the locus of the observed effects of switching was in written language processing or in speech production, by having the participants listen to sentences. Macnamara and Kushnir (1971) further mentioned that listening stimuli would remove a source of variation, i.e., self-pacing, as they can be played at the same speed. Monolingual English and monolingual French sentences, and those with

one and two language switches were prepared. The sentences were recorded on one channel of a two-channel tape recorder. On the other channel, an impulse was recorded to coincide with the beginning of each sentence. The participants listened to each sentence and made a judgement as to the truthfulness. Results showed that it took longer to process mixed sentences than monolingual ones in listening as well.

These early studies are, however, accompanied by a number of methodological issues. Characteristically, a measure of the switch cost was calculated by subtracting the overall response latencies associated with naming/reading monolingual passages, or lists of words, from those associated with the mixed-language presentation and dividing the difference over the number of language switches in the mixed presentation. It was therefore not possible to find out whether it was easier to switch from the non-dominant language to the dominant one or vice versa. With averaging procedures, the role of the bilingual's relative proficiency between the two languages was also not considered, as was the possible effect of current language use on the relative ease of switching (Meuter, 2005, p. 351).

Taking these issues into consideration, Meuter and Allport (1999) asked which direction is more difficult to accomplish and whether the ease of language switch would be affected by variations in the bilingual's proficiency in two languages, and whether the cost of a switch to one language would vary as a function of the number of preceding trials in the other language. Sixteen participants who spoke English either as their L1 or L2 were recruited. The native English speakers had a history of learning an L2 at university level and at least a one-year stay in the relevant country. Those who spoke English as their L2 had been in the UK for at least a half year at the time of the study and were enrolled in full-time study or research where English was solely used for communication. Regular language switches in spoken language were reported by all the participants. A self-paced numeral-naming task was administered to compare degrees of efficiency in recalling and producing numbers (1 to 9) between in L1 and L2. The numbers were presented one by one in lists ranging in length where switch and non-switch trials were given in an unpredictable order. The language in which a list of numbers to be read aloud was cued by colour, blue

for English, and yellow for French. Response times were recorded for every single trial, switch and non-switch, to test their relative strength hypothesis, which states that the size of the switching costs is subject to the relative strength of the bilingual's two languages (i.e., whether the switching cost is larger for a switch of language to the stronger L1 than for a switch to L2), hence, a larger switching cost was predicted for a switch into the dominant L1 than for a switch into the weaker L2.

Overall reaction times on switch trials (i.e., when participants were required to use a different language from the one in the previous trial) were slower than on non-switch trials. As predicted, a larger switching cost was observed when switching from the weaker L2 to the dominant L1, but not vice versa, hence, on switch trials responses in L1 were slower than in L2. This result resembles a phenomenon called task set inertia (Allport et al., 1994), which states that task-switching costs are derived from the active inhibition of one of two mutually competing tasks (or languages), which is then involuntarily carried over into the processing of the following task (or language) (Meuter & Allport, 1999). As seen in their results, producing a weaker L2 requires active inhibition of the competing L1, and this inhibition persists into the following trial, thus yielding a larger switching cost when moving from L2 to L1. To account for this counterintuitive language switching cost, Meuter and Allport (1999) divided the participants into two groups depending on their relative language proficiency (i.e., their speed of number naming in L1 against L2), which was the mean of median naming reaction times in L1 and L2 for all non-switch trials before the first language switch. As predicted, the switching cost differences between switch and non-switch trials were found smaller among participants with almost equal proficiency in the two languages. Therefore, a large asymmetrical switching cost is most likely to be found among participants with unbalanced proficiency in their two languages.

To deepen the understanding of bilingual language selection (Abutalebi et al., 2007), recent studies have utilised brain imaging in, for example, translation and switching tasks (Price et al., 1999), sentence-translation tasks (Lehtonen et al., 2005), and picture naming tasks (Hernandez et al., 2000; Wang et al., 2007), which put a

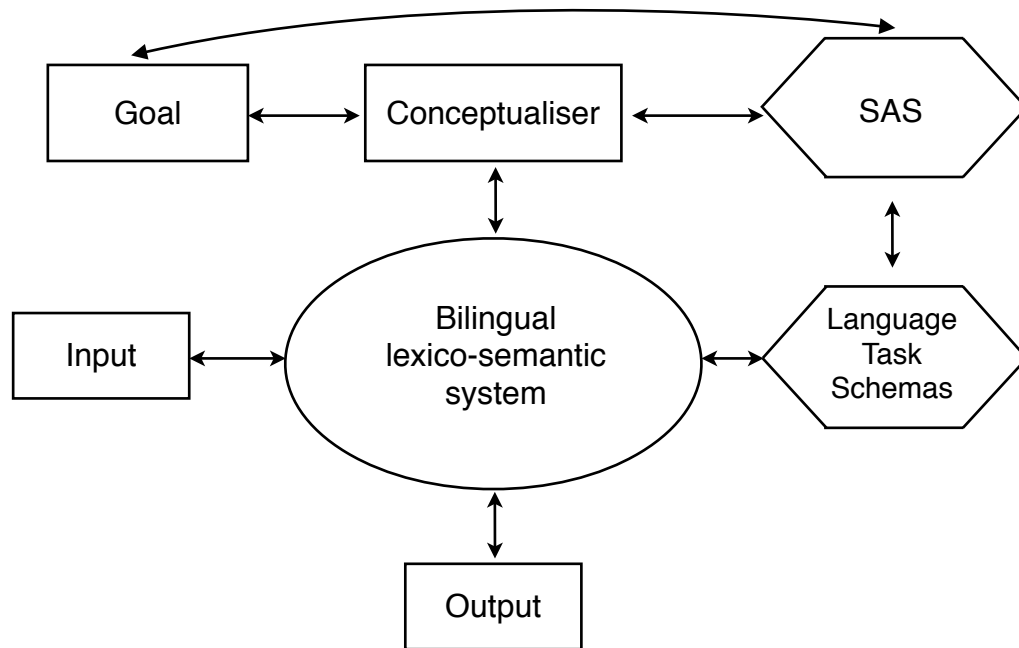


Figure 2.8. The inhibitory control model of bilingual language control by Green (1998).

cognitive load that relies on the general cognitive control mechanisms (Abutalebi & Della Rosa, 2012, p. 530). Before describing these studies that have started characterising the neural basis of bilingual language control processes (Abutalebi & Della Rosa, 2012, p. 529), the central concept of bilingual language control, conceptualised in the model called the inhibitory control model (Green, 1986, 1998), will be presented in the next section.

2.5.2 *Green's (1986, 1998) inhibitory control model*

“Where a person wishes to speak one language only, this language must be selected and the output from the other language system inhibited” (Green, 1986). The model that has proposed a bilingual’s control of her two languages (especially in speech production) is the inhibitory control (IC) model of bilingual language control postulated by Green (1986, 1998) (Figure 2.8). He was motivated to propose the model due to the lack of generality of explanations for the effects of brain damage on both normal and aphasic individuals and their speech errors and recovery patterns.

The IC model puts the supervisory attentional system (SAS) (Norman & Shallice, 1986) as its central construct (Figure 2.8). The term “schema” used in the model refers to not structures in long-term memory, but mental devices or networks that individual bilinguals may build or adapt instantly so as to accomplish a specific task. The schemas may include those for business meetings, letter writing, and conversational exchanges. The SAS functions to command the process of retrieval, adaptation, and construction or modification of current schemata and monitor their working according to task goals.

Green (1998) draws evidence for the role of frontal lobes in controlling language tasks from brain lesion studies that monolinguals with frontal lobe lesions perform poorly on Stroop tasks (Perret, 1974) and sentence completion tasks which especially call for inhibition of prepotent responses (Burgess & Shallice, 1996). Frontal lobe areas (e.g., DLPFC, ACC, SPL, and left caudate) have been identified in recent studies as loci of attention maintenance (DLPFC) (e.g., Holtzheimer et al., 2005; Osaka & Osaka, 2007), conflict-monitoring inhibitory process (ACC) (e.g., Abutalebi et al., 2007; Osaka & Osaka, 2007), focusing attention (SPL) (e.g., Osaka & Osaka, 2007; Smith & Jonides, 1999), and language selection (left caudate) (e.g., Abutalebi et al., 2000, 2007; Crinion et al., 2006). Based on information in long-term memory, conceptual representations are created by a conceptualiser, prompted by a task goal to attain some effect by means of language. The SAS and the lexico-semantic system along with language task schemas mediate the communicative and planning intention. Competition occurs within language task schemas (e.g., translation schemas or word production schemas) in order to control output from the lexico-semantic system. Decision on what word to produce calls for specifying the required language to be passed on by the SAS to the language task schemas. The conceptualiser then transfers conceptual information to the lexico-semantic system (Green, 1998).

Selection of a word in a chosen language is achieved through the inhibitory mechanism which functions to suppress the activation of the lexical representations of the non-target language (Green, 1986, 1998; Meuter & Allport, 1999). Bilingual

language control, Green (1986, 1998) suggested, is achieved by reactively inhibiting the lexical nodes in the non-target language (i.e., inhibition is applied only after a lexical node has been activated from the conceptual system (Costa et al., 2006)). Grosjean (1998, 2000) suggested that it is achieved by triggering a different level of activation in the two lexicons, which may be carried out by increasing the level of activation of the target language (i.e., by putting a bilingual in a monolingual mode where only one language is active). There have been a good number of findings in favour of inhibition as a key mechanism in bilingual language control and lexical selection in speech production (e.g., Abutalebi & Green, 2007; Meuter & Allport, 1999; Wang et al., 2007, 2008, 2009), however, only a few have been investigated on speech comprehension (e.g., Abutalebi et al., 2007, 2012; Verhoef et al., 2009). The next section will present research findings from these few studies and executive control processes involved in language control in the auditory domain.

2.5.3 Cognitive mechanisms of language switching and control

Since a bilingual's L1 and L2 have overlapping or partly overlapping neuroanatomical bases (e.g., Chee et al., 1999; Klein et al., 1995, 1999; Rodriguez-Fornells et al., 2002), bilingual individuals must necessarily possess effective neural mechanisms to control and regulate the activation of their two language systems (Abutalebi & Della Rosa, 2012, p. 529). It is suggested that language switching requires the participation of cognitive control for updating the contents of working memory, the participation of attention, and the decision to change the language in the present context of the performance (Rodriguez-Fornells et al., 2006, p. 158).

Price et al. (1999) visually presented words to the participants and they were given translation and language switching tasks while their brain activation was scanned using PET. Performing these tasks activated different parts of the brain. In particular, the translation task caused increased activation in areas responsible for general executive control such as the ACC and basal ganglia structures. Similar results are reported in a sentence translation task with fMRI (Lehtonen et al., 2005).

Increased activation in the left prefrontal cortex, especially, the dorsolateral prefrontal cortex (DLPFC), has been found in language switching (Hernandez et al., 2000; Holtzheimer et al., 2005; Wang et al., 2007). Remarkably, switching into the weaker L2 causes equal activation in the left DLPFC and ACC (Wang et al., 2007). The ACC and left caudate are recruited to resolve the conflict between two possible responses whereas the DLPFC is involved in resolving the conflict caused by the input ambiguity (Van Hueven et al., 2008).

These brain structures have been found to be involved in controlling interference from the non-target language in tasks such as naming (e.g., Rodriguez-Fornells et al., 2005) and reading (e.g., Rodriguez-Fornells et al., 2002). Abutalebi et al. (2008) have also shown increased activity in the left caudate and ACC when naming in L1 in a bilingual context where L2 stimuli may have occurred to create a fully bilingual condition. Bilinguals seem to cope with L2 interference during language production by recruiting generic “executive function” brain areas, such as the left DLPFC and ACC (Rodriguez-Fornells et al., 2006). Recently, Abutalebi et al. (2012) have demonstrated the involvement of the ACC in conflict monitoring in the picture naming task. As described in the section of working memory (see 2.4.2), these executive control areas are recruited to monitor and resolve conflicts when faced with conflicts (e.g., Weissman et al., 2003) and maintain attention on the target (e.g., Osaka & Osaka, 2007), which are also important for language control in bilingual language processing as shown above.

Although these studies have shown that a cognitive network recruited during word translation and language switching is also employed in general cognitive control processes (Miller & Cohen, 2001), none of these studies addressed the neural substrates of language switching in speech comprehension (Abutalebi et al., 2007).

Rinne et al.’s (2000) study is one of the few studies which investigated the brain activation patterns during speech comprehension. Professional interpreters were recruited in their study and were given simultaneous interpreting (SI) and shadowing tasks. PET revealed that SI task, especially interpreting into the non-dominant language (i.e., from L1 to L2), activated predominantly the left DLPFC, whereas the

shadowing task elicited bilateral activations of the temporal and posterior frontal areas related to hearing and speaking aloud as well as bilateral activations in the cerebellum. Their results (see also Tammola et al., 2000) suggest that SI is harder from the dominant to the non-dominant language, requiring more neural resources (de Groot & Christoffels, 2006). Neuropsychological evidence is in line with the results that the use of the weaker language requires the involvement of the DLPFC (Meuter et al., 2002).

In the light of the lack of studies on language switching and language control in speech comprehension, Abutalebi et al. (2007) investigated neural correlates of language switching during comprehension of auditorily presented narratives that contained unpredictable language switches from L1 to L2 and vice versa in highly-proficient Italian-French bilinguals who varied in the amount of exposure to L2. Two types of switches, regular and irregular switches, were included in the stimuli. Narratives with regular switches were passages that followed at major constituency boundaries (e.g., *Il piccolo principe* (Italian: The Little Prince) *qui m'a posé beaucoup de questions* (French: who has asked me a lot of questions), respecting the boundary between verb phrase and relative clause), and narratives with irregular switches were passages that did not follow at constituency boundaries (e.g., *J'ai* (Italian: I have) *risposto* (French: answered), disrespecting the boundary between the auxiliary verb and the participle of the lexical verb)). In irregular switches, language switch was placed inside the noun phrase (i.e., between the determiner and the noun, etc.) and verb phrase (i.e., between the auxiliary verb and the principle of the lexical verb, etc.). The participants were asked to listen to the narratives with regular and irregular switches while their brain was scanned with fMRI. They were given ten comprehension questions for each narrative. Differences in brain activation for different switches were analysed at four points: (1) regular switches from L2 to L1; (2) regular switches from L1 to L2; (3) irregular switches from L2 to L1; and (4) irregular switches from L1 to L2.

Results indicated that processing regular and irregular switches activated different regions of the brain and the brain network serving the general executive

control (i.e., the ACC and left caudate) was found to be involved when switching from the dominant language to the weaker language. This is in conflict with the general findings in bilingual language switching in production studies that it is more costly to switch from the less dominant language to the dominant language (e.g., Meuter & Allport, 1999). Abutalebi et al. (2007) suggest that during comprehension in the weaker language, the dominant language is not actively inhibited because comprehension is a more passive task and competition between languages may not be as prominent as in production. The cost of switching may not emerge to deal with inhibition of the dominant language during comprehension in the weaker language, but rather may appear if required to strongly activate the weaker language when switching from the dominant to the weaker language. It could also be, as caudate activity has been found to increase corresponding to the degree to which a new salient sound interferes with the current cognitive focus (e.g., Crinion et al., 2006; Zink et al., 2006), the less-exposed language in their study was perceived as a more salient stimulus, requiring the reallocation of cognitive resources through more controlled processing. The finding of a cognitive control network during speech comprehension strongly calls attention to the fact that the bilingual brain is equipped with a dedicated cognitive mechanism responsible for the correct selection of the intended language (Abutalebi & Della Rosa, 2012, p. 531).

2.6 Auditory attentional control

A bilingual context where both of a bilingual's languages are activated and maintained available even when one of them is used (e.g., Crinion et al., 2006; Rodriguez-Fornells et al., 2005; Thierry & Wu, 2007) requires a bilingual individual to employ attentional control to select a form that meets all the linguistic criteria for form and meaning but is also part of the target language and not the competing system (Bialystok, 2009). Compared to monolingual children, bilingual children may start developing enhanced cognitive control since they are faced with switching and attentional control demands from early on (Bialystok, 1999). The attentional control

demands may arise from anything that is related to bilingual language processing. In settings where sources of information competing with the task-relevant source need to be inhibited, working memory capacity is required to employ attentional control (e.g., Engle et al., 1999). If the bilingual advantage on visual tasks measuring executive functions is a valid finding, it should also be generalisable to auditory tasks tapping these functions (Soveri et al., 2011).

In the context of auditory speech processing, bilingual listeners need to maintain their attention to the relevant language, e.g., L2, and inhibit another, e.g., L1, although it is practically implausible to deactivate their L1 completely (Weber, 2001), and this is where auditory attentional control (e.g., Hill & Miller, 2010), subserved by general executive control (e.g., Engle & Kane, 2004), plays its role. Attentional control, as described earlier, is important to strengthening the activation of representations relevant to the current task but also important to the discarding or inhibition of task-irrelevant representations that would interrupt performance of the task (Engle, 2010, p. S22). Auditory attentional control has been investigated utilising the dichotic listening (DL) paradigm (e.g., Alho et al., 1999; Asbjørnsen & Hugdahl, 1995; Hugdahl & Andersson, 1986; Hugdahl et al., 1999, 2000; O'Leary et al., 1996). The effect of attention on DL performance is to inhibit, or suppress, the processing of the irrelevant signal (Hugdahl, 2003, p. 459). Performance in the DL tasks has been shown to be highly correlated with measures of working memory capacity (e.g., Conway et al., 2001; Hugdahl et al., 2009; Soveri et al., 2011; Thomsen et al., 2004), that is also evidenced by cognitive neuropsychological studies showing that DL activates frontotemporal areas for executive control processing (e.g., Jäncke & Shah, 2002; Thomsen et al., 2004).

The DL paradigm has been also employed to investigate auditory laterality, which is the study of how speech is processed in each hemisphere. Auditory laterality studies with the DL task have focused on (1) hemispheric asymmetry for the processing of phonetic stimuli (Hugdahl, 1995, 1997), (2) temporal lobe function and memory processing (Wester et al., 1998; Wester & Hugdahl, 1995; Hugdahl et al., 1993), (3) vigilance and attention (Asbjørnsen & Hugdahl, 1995; Løberg et al.,

1999), and (4) inter-hemispheric interaction and callosal function (Reinvang et al., 1994) (as cited in Hugdahl, 2003, p. 441). Of particular relevance to the current dissertation in relation to auditory laterality are studies on bilingual language lateralisation, i.e., language dominance in the brain (e.g., Flege et al., 2002; Paradis, 2003). For example, Morton et al. (1998) showed in the DL task that bilinguals with an earlier induction age demonstrated a comparable laterality index to monolingual peers, whereas those with a later induction age indicated a more left hemisphere involvement in processing DL stimuli.

The following sections present an overview of the DL studies which investigated auditory attentional control, represented by the cocktail party effect (e.g., Cherry, 1953; Cherry & Taylor, 1954; Moray, 1959), among both monolinguals and bilinguals, and, although controversial (e.g., Paradis, 1995, 2003), the language lateralisation in the bilingual brain.

2.6.1 Cocktail party effect revisited

The cocktail party phenomenon is found, e.g., in an environment where listeners can respond to their own name even though the signal/noise ratio is low (Moray, 1959). One of the first studies on this selective attention in listening was conducted by Cherry (1953, also Cherry & Taylor, 1954) in the DL task he developed, where the task was to shadow (i.e., repeat aloud) the message presented to one ear and ignore another message presented to the other ear. Cherry demonstrated that monolingual listeners were able to distinguish auditory information they needed to focus on at a given time and disregard unnecessary information by using physical characteristics such as gender of the voice, voice intensity or speaker location. Cherry also found that listeners seldom noticed when the message in the unattended channel was in a foreign language or reversed speech, and concluded that unattended auditory information receives practically no processing, which was supported by finding that very little memory was allocated for processing unattended words although they were presented 35 times each (Moray, 1959). Treisman (1964) also found that voice

differences (i.e., male versus female) make it easier to ignore the unattended irrelevant message when messages are presented dichotically (i.e., mixed and played to both ears). Broadbent (1958) developed a theoretical model of selective auditory attention which argues that simultaneously presented messages are accessed in parallel. One of the messages is filtered out, once identified as irrelevant, based on its physical features with the other message kept in the buffer for later processing. The filter processes the meaning of the message thoroughly while preventing the limited capacity mechanism from overloading.

Later studies, however, have shown that the unattended message is not entirely unprocessed (Lachter et al., 2004), since the acoustic features of to-be-ignored speech are processed to a certain degree, as a listener may detect physical changes in it (a change from a male to female voice) (Alho et al., 2003). In fact, Moray (1959) reported that 33% of the participants noticed their name presented to the unattended channel. Moray's (1959) study was replicated by Wood and Cowan (1995) who found that 34.6% of the participants noticed hearing their name in the unattended message. Using semantically related (i.e., synonyms, e.g., *hurt-harm*, *big-large*, *shape-form*) and unrelated words, Treisman, Squire, and Green (1974) found that the synonym in the unattended channel slowed down reaction times to the word in the attended channel that had to be shadowed, suggesting that the to-be-ignored semantic information breaks through the attention filter and affects processing of the to-be-shadowed information.

Conway, Cowan, and Bunting (2001) investigated why some demonstrate the cocktail party effect, i.e., noticing their name in the unattended channel, and others do not, taking individual differences in working memory capacity into consideration. Conway et al. (2001) gave the participants the DL task in which relevant monosyllabic words were presented in a female voice and irrelevant ones in a male voice. Each participant's name was recorded in the same male voice and interpolated in the irrelevant message and it occurred after 4 and 5 minutes of shadowing, each name replacing a word (Wood & Cowan, 1995). The participants' WMC was assessed with the OSPAN (Turner & Engle, 1989) and their performance in the DL

task was compared between high-span subjects (HSSs) and low-span subjects (LSSs). As a result, more LSSs (65%) reported hearing their name, whereas only 20% of HSSs reported hearing their name. LSSs also made significantly more shadowing errors than HSSs. It was found that the concurrent presentation of the name with the target word led to distraction much more so for LSSs. On the contrary, HSSs were found to be more capable of suppressing irrelevant information from the unattended channel and were hence less likely to hear their name, which suggests that HSSs are less vulnerable to a consequent interruption on relevant task performance. Conway et al. (2001) demonstrated the importance of WMC for investigating selective attention in the DL task.

A recent study by Colflesh and Conway (2007) investigating whether individual differences in WMC would appear in the DL task has also demonstrated that English monolinguals with greater WMC are better able to divide their attention and achieve the task goal. The involvement of WMC was manifest especially when performing attention tasks that place greater demands on executive attention (i.e., dividing attention to both channels and shadowing target words in the attended channel while trying to detect one's name in the unattended channel). Baddeley (2007, p. 185) suggests that high span subjects normally use attention-demanding strategies to enhance performance. Indeed, WMC is suggested to be most required when task-relevant information has to be actively maintained to guide response selection, especially if task-irrelevant information is also available (Engle & Kane, 2004). Another study of the effect of irrelevant speech on reading comprehension (Sörqvist et al., 2008) shows that people with higher WMC are less affected by irrelevant speech while reading than those with smaller WMC. They conclude that the poor performance among poor comprehenders is due to their lack of updating ability, which is the ability to select relevant information for further processing (Sörqvist et al., 2008). These results would suggest that low span participants are unable to effectively attend to the shadowed channel, and relevant information, whether visual or auditory. They are also unable to inhibit irrelevant information at the time when it

is presented, meaning that they are more vulnerable to coinciding irrelevant information.

This section reviewed classic DL studies and emerging importance of the role of WMC in attentional and selective control found in the DL paradigm among monolinguals. The next section presents most relevant DL studies on bilinguals and their executive control in maintaining their attention to the relevant and inhibiting the irrelevant speech stimuli.

2.6.2 *Auditory attentional control among bilinguals*

Bilingual advantages compared to monolingual peers, as mentioned earlier, have been shown on many tasks that especially require executive control against an interrupting response, such as the Simon task (e.g., Bialystok et al., 2004), the attentional network task (e.g., Costa et al., 2008), and task switching (e.g., Prior & MacWhinney, 2010). Since these and other studies have provided evidence for a bilingual advantage in tasks calling for inhibition of task-irrelevant cues (e.g., Bialystok, 2001), Hugdahl et al. (2009) hypothesised that the bilingual advantage in executive functions should also emerge in the forced-attention DL paradigm, where attention is differentially directed (so forced) to either left or right ear, or either ear. In the light of previous study results and Hugdahl et al.'s (2009) hypothesis, Soveri, Laine, Hämäläinen and Hugdahl (2011) investigated the possible bilingual advantage within the forced-attention DL paradigm.

In the domain of auditory speech processing at a low speech level, Soveri et al (2011) demonstrated a bilingual advantage among early Finnish-Swedish bilinguals compared to monolingual peers in processing and recalling consonant-vowel syllable pairs (/ba/, /da/, /ga/, /pa/, /ta/, /ka/) presented to both ears simultaneously. The participants were forced to focus their attention to one of their ears (forced-left: FL and forced-right: FR) and asked to recall as many syllable pairs as possible presented to that ear. The bilinguals performed significantly better in both conditions than the monolinguals in spite of the cognitive demand caused by the attention shifting and

attention focusing. Hugdahl et al. (2009) has shown that switching between ears and maintaining attention to one of them entails effective inhibition of interference from the stimuli presented to the other ear and guiding attention to the attended ear. The results from their study suggest that the bilinguals have more effective control in focusing attention and suppressing task-irrelevant stimuli (Soveri et al., 2011).

The most recent study, that is also most relevant to the current dissertation, has undertaken an investigation of bilinguals' executive control advantage in suppressing sentence-level interference during auditory sentence comprehension among Italian-English bilinguals and monolinguals of each of these languages (Filippi et al., 2012). The authors sought to explore if bilinguals would demonstrate an advantage compared to their monolingual peers in comprehension of spoken sentences in the face of other spoken sentences, which may be arguably a more cognitively demanding situation than when there is no interfering information, i.e., comprehending only one of their languages. The participants were given a listening task where they were required to listen to a target sentence heard in a female voice in one ear and choose a picture of a corresponding agent of the sentence shown on a computer screen, while suppressing a distracting sentence heard in a male voice in the other ear. The target and distracting sentences were either canonical with Subject-Verb-Object (S-V-O) word order (e.g., *The cat is biting the dog*) or non-canonical with (O-V-S) word order (e.g., *The cat is bitten by the dog* or O-S-V: *It's the cat that the dog is biting*), and they were played in two conditions: interference and no-interference conditions. In the interference condition, the target and distractor sentences were either canonical or non-canonical and presented in the following language pairs: Italian (ITA)/Italian (ITA), English (ENG)/English (ENG) or different language trials (i.e., ITA/ENG, ENG/ITA). In the no-interference condition, only target sentences were played. The bilingual participants took the listening task in both languages, but monolinguals were instructed to respond to the target sentences when they were heard in their native language and to guess when the target sentences were not played in their native language. The hypothesis was that Italian-English bilinguals would show an advantage at selecting the target message in the

presence of linguistic interference especially in the case of non-canonical sentences because the agent of the sentence is not in first position typical of English sentences and so any initial thematic assignment must be suppressed in favour of a noun heard later (Filippi et al., 2012).

Results show that the bilingual participants were better at processing highly demanding sentences (non-canonical Italian sentences) in the face of interfering Italian sentences than the Italian monolingual participants. There were no significant differences in reaction times when identifying an agent between the two groups. The bilingual participants were able to identify an agent at an equal speed regardless of the language presented to the other ear, and in fact they were faster at processing the target sentence when there was no interfering sentence than Italian monolinguals, suggesting that bilinguals are better at resolving conflicts from interfering information that is at the level of sentence interpretation. The authors conclude that the bilinguals' control of other interfering sentences in the two languages be ascribable to cognitive control enhanced by their experience in using both languages at work on a daily basis. The bilinguals' second language (L2) proficiency was shown to be related to the capacity to better control interference from both of their languages. Bilinguals with higher L2 proficiency were found to be better able to resist interference when the target and interfering sentences were in Italian and when the target was English and the distractor was in Italian. Hence, the greater the bilingual proficiency, the better able bilinguals are to screen out competing, task irrelevant, L1 speech (Filippi et al., 2012).

Although measures of general fluid intelligence such as the Raven's Matrices (Raven, 1947) have been found to be highly correlated with those of executive functions (i.e., cognitive/inhibitory control) (e.g., Conway et al., 2003; Duncan et al., 2008; Kane & Engle, 2002), IQ assessed by the Raven's Matrices in Filippi et al.'s (2012) study was not shown to be correlated with the ability to resolve interference from the other sentence, which is a complex cognitive task and would evidently require executive control subserved by the prefrontal cortex (PFC). Duncan et al. (2000) in their PET study used a non-verbal (figural) task, the Raven's Progressive

Matrices (Raven et al., 1988) and a verbal task adapted from a standard letter-based problem-solving task, called Letter Sets from the ETS Kit of Factor-Referenced Tests (Ekstrom et al., 1976), and found that the figural task elicited bilateral activation (regions recruited in a wide range of visuospatial tasks), whereas the verbal task activated only the left dorsolateral PFC (DLPFC), which has now been identified as the centre of executive control in both verbal and non-verbal tasks (e.g., Abutalebi et al., 2000; Osaka & Osaka, 2007). The left DLPFC and its surrounding areas have been found to be activated when engaged in working memory tasks which put dual task demands such as the Reading Span Test (Daneman & Carpenter, 1980) and the Operation Span Task (Turner & Engle, 1989). Bilingual auditory comprehension is also subserved by the brain's general executive control network (Abutalebi et al., 2007). Comprehension processes involved in the listening task in Filippi et al.'s (2012) study were all linguistic and involved cognitive conflicts and language switching, hence, there must have been an increased brain activation in the participants' left DLPFC. Language switching requires the participation of cognitive control for updating the contents of working memory, the participation of attention, and the decision to change the language in the present context of the performance (Rodriguez-Fornells et al., 2006). On these accounts, it would be more sensible to employ executive control tasks, e.g., the RST, which entail processing and storage, inhibition of unwanted responses, shifting between tasks and mental sets, and updating and monitoring of working memory representations (e.g., Soveri et al., 2011), in order to show what aspects of bilingualism would be involved in comprehension and cognitive and linguistic conflict resolution in spoken speech processing.

2.6.3 *Auditory laterality*

In the DL task, there has been found a general tendency to recall an auditory verbal stimulus presented to the right ear more often than a comparable stimulus presented simultaneously to the left ear (e.g., Bryden, 1963, 1988; Hugdahl, 1995, as cited in

Westerhausen & Hugdahl, 2010, p. 470). This is called the right-ear advantage (REA), and has been found when their attention is directed to the right ear (forced-right: FR) and even when the participants are not forced to attend to either channel (i.e., non-forced: NF). They are also able to shift their attention to their left ear (i.e., forced-left: FL) and recall as much information as from their right ear (so left-ear advantage (LEA)).

What is more robust about the bilingual advantage found in Soveri et al.'s (2011) study shown above with regard to auditory laterality is that the bilinguals have shown effective attention shifting to the left ear in the FL condition. Previous research has revealed a right-ear advantage (REA) among healthy right-handed individuals, that is, it is easier to recall information presented to the right ear than to the left ear (e.g., Bryden, 1963; Hugdahl, 2003; Kimura, 1967; Morton et al., 1998). It has been found that patients with lesions in the posterior parts of the corpus callosum (a massive tract containing roughly $200\text{--}350 \times 10^6$ fibres connecting both hemispheres (Jäncke & Steinmetz, 2003, p. 204)), including parts of the isthmus (where the auditory fibres cross over), show an almost perfect left ear extinction effect, and a corresponding almost perfect 100% REA effect (e.g., Pollmann et al., 2002). This crucial finding shows that the left ear stimulus is not processed in the right hemisphere but has to be transferred over the corpus callosum in order to be processed in the temporal lobe in the left hemisphere (Hugdahl, 2003, p. 447). Hence, successful attention shifting to the left ear requires an intact brain organisation and stronger cognitive effort.

fMRI studies (e.g., Jäncke & Shah, 2002; Thomsen et al., 2004) have found evidence for the idea that the FL condition involves executive processing/control, i.e., the ability to select a weaker, task-relevant response (or source of information) in the face of competition from an otherwise stronger, but task irrelevant one (Miller & Cohen, 2001, p. 170). Compared to the FR condition, the FL condition engages more of the left middle temporal gyrus and the anterior cingulate (e.g., Hugdahl et al., 2009; Thomsen et al., 2004), which have now been found to be responsible for maintenance of attention, conflict-monitoring and inhibition (Osaka & Osaka, 2007,

p. 114; Rodriguez-Fornells et al., 2002). Thus, the finding that the bilinguals recalled more syllable pairs in the FL condition compared to the monolinguals (Soveri et al., 2011) suggests that bilinguals have an advantage for executive control processing.

Different ear advantages for processing phonologically different properties have been reported (e.g., Rimol et al., 2006; Speaks et al., 1981). A stimulus dominance effect (e.g., Speaks et al., 1981) is an effect where certain phonological stimuli are recalled more frequently in the DL task irrespective of the attended ear. Voiced syllables, e.g., /ba/, /da/, or /ga/, are characterised by a shorter voice-onset time (VOT), whereas voiceless syllables, e.g., /pa/, /ta/, or /ka/, have a longer VOT (Westerhausen & Hugdahl, 2010, p. 477). Using pairs of voiced and voiceless syllables in the DL task, Rimol et al. (2006) found an REA when processing syllables in the same VOT condition (i.e., two stimuli are either voiced or voiceless). However, in a different VOT condition, a stronger REA was found when a voiceless syllable was presented to the right ear and a voiced to the left, and a significant LEA was found when the presentation of voiced and voiceless syllables was inverted (i.e., a voiced syllable to the right ear and a voiceless to the left), which may be due to the physical feature of the voiceless syllable having a longer VOT, allowing the listener to recognise it after a time lag in the attended ear (Berlin et al., 1973; Repp, 1978).

As seen above, an REA appears in the processing of speech stimuli, reflecting that language processing is localised in the left hemisphere. Although less predictable (e.g., Bloch, 1996; Morton & Siegel, 1991), an LEA has been found when processing emotional tone in word production (e.g., Bulman-Fleming & Bryden, 1994; Obrzut et al., 2001), and music (e.g., Griffiths et al., 1997; Shankweiler, 1966). Such findings show that an active processing of the non-verbal features of the stimuli takes place in the right hemisphere, indicating an LEA for the non-verbal features (Asbørnsen & Helland, 2006). Then, how do bilinguals process their two languages in their brain? Would they also show different ear advantages for each language?

Language laterality among bilinguals has been investigated with tachistoscopic, dichotic listening and time-sharing and dual-task paradigms, and it has been found that late bilinguals show lateral activation and mixed preferences of the two

languages, whereas early bilinguals show right hemispheric dominance in their L2 (Hull & Vaid, 2007; Paradis, 1990). One of the factors, which can influence hemispheric representation of language, is the age of acquisition (Vaid & Genesee, 1980). Languages acquired earlier tend to be more left-lateralised, whereas those acquired later tend to be bilaterally represented (e.g., Vaid & Hull, 2002). There are another four hypothetical arguments as for bilingual language lateralisation, which are (1) the L2 hypothesis that predicts that the right hemisphere (RH) is more involved in L2 processing relative to L1 processing of bilinguals (e.g., Genesee, 1982; Vaid, 1983); (2) the balanced bilingual hypothesis that claims that native-like proficiency changes hemispheric involvement, that is more RH involvement than monolinguals (e.g., Galloway, 1983); (3) the stage hypothesis (Obler, 1981) that says that acquisition of L2 at early developmental stages is strongly RH dominant, but at later stages the left hemisphere (LH) gets more involved; and (4) the manner of L2 acquisition hypothesis that predicts that more RH is involved if L2 is taught in an informal setting (i.e., naturalistic communicative settings), whereas if taught in a formal setting (i.e., learned in school), more LH involvement can be seen (Hull & Vaid, 2005, p. 484).

Some studies have shown how a bilingual's L1 and L2 are processed in the brain during listening. Brain activation during (diotic) story listening among bilinguals has been studied with PET by Perani et al. (1996, 1998) and fMRI by Dehaene et al. (1997). Perani et al. (1996) found that listening in L1 (Italian) activated the perisylvian language areas (inferior frontal gyrus, the superior and middle temporal gyri, the temporal pole, and the angular gyrus) and the right cerebellum. Listening in L2 (English), on the contrary, activated only left and right superior and middle temporal areas, and the bilateral parahippocampal region was also activated. Perani et al. (1996) suggested on these results that some brain areas are formed by early exposure to the mother tongue, and are not necessarily activated by the processing of one's second language to which they have a limited amount of exposure later in life.

Dehaene et al. (1997) showed that listening in L1 (French) induced activation of the same areas of the left temporal lobe (superior temporal sulcus and superior and

middle temporal gyri) across participants, however, brain activation patterns varied between participants when listening in L2 (English). Most of the participants (six out of eight) showed left-lateralised activation, whereas the rest (two) showed complete right-lateralised activation. Dehaene et al. (1997) concluded that L1 acquisition relies on a devoted left-hemispheric cerebral network, while late L2 acquisition causes great variability in its cortical representation (from complete right lateralisation to standard left lateralisation for L2) (Fabbro, 2001).

Perani et al. (1998) further investigated brain activation patterns when listening in L1 and L2, considering the effect of the age of L2 acquisition (early: before 4; late: after 10), while controlling for L2 proficiency (constantly high across participants). Similar activation patterns for the two languages were found, not only among the early bilinguals, but also among the late bilinguals, which led Perani et al. (1998) to conclude that, in language comprehension at least, attained L2 proficiency is more important than the age of acquisition as a determinant of the cortical representation of L2 (p. 1841). This finding is supported by later studies (e.g., Abutalebi, 2008; Abutalebi et al., 2005) that in general attained L2 proficiency is a stronger determinant of the brain organisation of language (especially semantic processing) than age of acquisition (AoA) (cf. Wartenburger et al.'s (2003) study on the influence of AoA on the cerebral organisation of syntax, i.e., more activation or less efficient representation of grammatical processing if the language is learned late).

More recently, D'Anselmo, Eritrea, Zucchini, Tommasi, and Brancucci (2013) investigated the hemispheric specialisation for bilingual languages using the DL paradigm in which thirty pairs of words that were phonemically same and had the same stress with different initial consonants (e.g., *packing-backing*, *pity-bitty*, *tummy-dummy*) were presented in each of the bilingual participants' languages. Two groups of late bilinguals with English as L2 were chosen from speakers of L1 German and L1 Italian, whose languages have similarities and differences with English, to investigate the language lateralisation as a function of their similarity. The task was to indicate which word they heard better by choosing a corresponding

word shown on the display. The participants were instructed to pay their attention to both ears, hence, the DL condition in their study can be said to be the NF condition. The side of presentation of DL stimuli and response screen was fully counterbalanced accordingly. The authors hypothesised that along with the REA for perceiving all of their languages, there would be different L2 asymmetries in the two groups because of the similarities between English and German, and dissimilarities between English and Italian, possibly showing a similar lateralisation pattern between similar languages.

Results showed that there was an overall REA among both groups of bilingual participants, indicating a left hemispheric specialisation in the perception of words in both L1 and L2 in healthy bilingual individuals. Linguistic similarities between the bilinguals' two languages were found to have an impact on bilingual language lateralisation for processing both their L1 and L2. In German-English bilinguals whose languages derive from the same root (i.e., German and English Anglo-Saxon languages), there was a stronger REA for L2 (English) than that for L1 (German). In Italian-English bilinguals whose languages derive from different roots (Italian, a Latin language, and English), however, strengths of the REA were no different for both L1 (Italian) and L2 (English). Ezzatian et al. (2010) also showed the effect of factors influencing the difference in listening performance in L1 and L2, that are the degree of similarity between L1 and L2, duration of exposure to the L2, knowledge of the L2 language vocabulary and grammatical structure, frequency and extent of L2 use. Since the participants were equal in their L2 proficiency, age of L2 acquisition, and exposure to L2, D'Anselmo et al. (2013, p. 1192) stated that this phenomenon could be accounted for by language-specific factors, that is, a strong similarity between two languages produces interferences within the multifaceted neural mechanisms implemented in the speech areas devoted to their processing, which results in an exile of L2 to different, possibly in part contralateral, brain areas, whereas the same neural speech mechanisms would be less affected by interference when the two languages (L1 and L2) are substantially different.

There have been many factors that are reported to influence bilingual language lateralisation as shown in a meta-analytic study by Hull and Vaid (2007), with a consistent and main finding that L2 processing causes a stronger neural activation and involves more brain regions (e.g., Indefrey, 2006), plausibly due to lower L2 proficiency (e.g., Vingerhoets et al., 2003), late onset of bilingualism, and less L2 exposure (Obler, 1981), relative to more proficient bilinguals (Indefrey, 2006). Since the degree of executive control capacity does also affect how much information can be retrieved from each ear (e.g., Conway et al., 2001), I consider not only L2 proficiency, but also executive control capacity, along with those experiential factors (e.g., the age of L2 acquisition, L2 exposure, length of L2 learning) in the investigation of auditory laterality in comprehension of meaningful passages in my dissertation.

2.6.4 *Preference in auditory processing*

The previous section reviewed DL studies and a consistent result was that more items are correctly reported from the right, relative to the left ear (i.e., REA) (e.g., Bryden, 1963; Hugdahl, 2003; Kimura, 1967; Morton et al., 1998). This REA has been reported among bilinguals when processing syllable and word pairs (e.g., Soveri et al., 2011; D'Anselmo et al., 2013). This section intends to present briefly how highly advanced bilinguals, i.e., professional simultaneous interpreters, use each channel when engaged in simultaneous interpreting between their languages, thereby presenting ear preference patterns for processing passages and favourable ear-to-hemisphere relationships for better performance.

Studies on language functions with regard to language lateralisation have shown different preferences among bilinguals depending on when they started learning L2, with early bilinguals showing overlapping brain areas for the two languages (e.g., Hernandez et al., 2000) and with late bilinguals showing left lateralised organisation (e.g., Klein et al., 1999) and on how balanced they are between the two languages, with moderately proficient bilinguals showing bilateral activation when listening to

L2 (e.g., Dehaene et al., 1997). Of the most relevance to the current dissertation is the study by Lambert (1993) where she investigated the efficiency of ear preference among simultaneous interpreters. She found that the left-ear-to-right-hemisphere route was more advantageous than the right-ear-to-left-hemisphere route in terms of decoding language A and encoding in language B (i.e., hearing the source language (L2) in the left ear and checking their orally interpreted L1 in the right ear). On the contrary, the right-to-the-left-hemisphere route was found efficient for interpreting from L1 to L2. She interprets the right-ear-advantage as reflecting a left temporal lobe specialisation for processing of simple speech sounds (Soveri et al., 2011) whereas the left-ear-advantage is represented in the RH for processing linguistic prosody, e.g., stress and intonation (Shipley-Brown et al., 1988).

Different hemispheric preferences among professional interpreters in semantic processing compared to student interpreters and fluent bilinguals have been also reported (e.g., Fabbro et al., 1991; Spiller-Bosatra et al., 1990). Professional interpreters are found to be better at detecting semantic errors than student interpreters, and they demonstrate an REA for this linguistic processing in L1 and an LEA for L2. It appears that extensive training in simultaneous interpretation alters hemispheric specialisation and triggers a re-organisation of attentive functions for verbal stimuli from both ears (Gran & Fabbro, 1989, p. 134).

Hamers, Lemieux, and Lambert (2002), following Lambert's (1993) and Lemieux's (1995) studies, investigated the effects of interpreting experience, age, and age of bilinguality on the hemispheric control of interpretation. Skilled interpreters and student interpreters received an interpretation task where they interpreted texts from L2 or L1 using either left ear, right ear, or both ears. As a result, not the age of bilinguality, but experience in interpreting was found to influence the quality of interpretation, regardless of the ear of input, since interpreters with long-term experience (seven years or longer) performed better than less experienced interpreters and there was no difference in interpretation performance between the participants with different starting ages of bilingualism. Hamers et al. (2002) conclude that decreased lateralisation (ear preference) can be

observed when interpreters accumulate extensive experience in interpreting and that a change in the choice of interpretation strategies might develop for a similar task according to an interpreter's experience with linguistic analysis.

Hence, ear preference, the use of an advantageous ear-to-hemisphere route for processing speech, may undergo changes through developments as a language user (presumably requiring as extensive experience and training as simultaneous interpreters accumulate). With bilinguals with relatively high L2 proficiency, this dissertation seeks to explore whether ear preference would be observed when listening to a stream of speech in one language and inhibiting another language that is semantically related and unrelated to the attended language, and how comprehension of one language and effective inhibition of another would be related to cognitive and experiential factors.

2.7 Everyday activity in speech comprehension: An aid for memory retention

Cognitive psychology routinely makes use of the online measure of information processing by calculating reaction times, and the input stimuli are usually given and processed in a matter of seconds, or at most a few tens of seconds. As stated earlier, bilingual studies have primarily focused on the processes of not larger linguistic units, but words or phonemes (de Groot, 2011, p. 4), that are usually processed in less than a second. Nevertheless, listeners perceive not only isolated words out of context, but sentences and passages (Ingvalson et al., 2014), which are often accompanied by note-taking in the real-life situations (Piolat et al., 2005). It was considered that investigating bilinguals in their (near) everyday situation would shed light on the cognitive mechanism of speech comprehension which was my primary goal in conducting the series of experiments presented in this dissertation. Hence, it was thought necessary to consider what listeners commonly do when they are engaged in speech comprehension of this kind of lengthy sentences that is *note-taking*. I used note-taking as an experimental manipulation to observe its effect on bilingual speech comprehension. Notes produced by the participants are not analysed

further as can be found in traditional note-taking research (e.g., Kiewra, 1989; Olive et al., 2002).

Note-taking is seen in everyday situations such as when writing down a phone number to make an inquiry, summarising on the blackboard in lectures, or making plans for a day. In fact, a lot of cognitive effort is required during note-taking as it involves comprehension, evaluation of what to be written down, deciding what to write, and actually writing them (Piolat et al., 2005), for which the central executive component of working memory (Baddeley, 2000) plays a significant role. This section presents brief summaries of characteristics of note-taking and cognitive processes involved in it.

2.7.1 Critical features of note-taking

Note-taking is different from simple copying of what is heard, observed, or thought, in that it is a complex activity that requires comprehension and selection of information and written production processes (Piolat et al., 2005). Note-takers not only need to comprehend and write down personally flavoured information (i.e., a private product typically intended to be meaningful only to the note taker (Piolat et al., 2005)) but, prior to that, they also need to perceive and filter the incoming sources, organise and restructure existing knowledge structures and, most importantly, they must store and integrate the freshly processed material (Makany et al., 2009).

The products of note-taking, i.e., notes, are short condensations of a source material that are generated by writing them down while simultaneously listening, studying, or observing (Piolat et al., 2005). Notes function to collect information during a lecture, in a book, or in any other situation that needs to be remembered, and can be regarded as external memories (e.g., Hartley, 1976; Hessels et al., 2009; Norton, 1981) that can be useful for later activities such as studying of lectures. Taking notes for oneself can in fact facilitate learning by fostering retention and connections of information (Piolat et al., 2005). It has been also found that the need

for deep comprehension enhances the function of note-taking for memorisation (Williams & Eggert, 2002).

Since note-taking is conducted under strict time pressure, note-takers make use of three common strategies (Piolat et al., 2005): (1) abbreviation procedures; (2) syntax transformation; and (3) physical formatting. With abbreviation procedures, spellings are shortened on lexical units such as *poss* for *possibility* (i.e., end truncation) and *recog^{ed}* for *recognised* (suffix contraction) (e.g., Kiewra & Benton, 1988). Syntax transformation refers to shortening statements of the original heard material. Syntactically transformed notes may look like ‘*more depth → qualificat^o to teach*’ (° for *-ion*) (e.g., Barbier et al., 2003). Notes may be physically formatted to save time in that they are itemised with important points, or arranged in tabulation, which often look like preparatory rough drafts of an essay (e.g., Kellogg, 1988).

2.7.2 Cognitive mechanism of note-taking

Note-takers are required to cope with several cognitive processes that are related to comprehension, writing and learning (Piolat et al., 2005), resorting to working memory capacity to attend, store, and manipulate information selected from what they hear (e.g., lectures) while also transcribing ideas just previously presented and processed (Kiewra & Benton, 1988).

Kiewra and Benton (1988) investigated the relationships between (1) scores on a test of information-processing ability, (2) notes taken during an assigned lecture, (3) test scores about that lecture, and (4) score on a course exam including several other lectures. In the test of information-processing ability used in their study, the participants were required to hear and re-order six scrambled 10-word sentences (e.g., *was urged or no come near forced to even one*. The correct order is *no one was forced or even urged to come near*). The task required the participants to hold and re-organise information simultaneously in working memory. The total correct was determined by subtracting the number of errors from the maximum score possible (10 out of 10 words). From notes taken during an assigned lecture, the numbers of

propositions and main ideas were identified. The participants were also given 18 multiple-choice questions specific about the lecture. They were then given 25 short-answer questions about six 50-minute lectures on a different subject.

Results showed that performance in the test of information-processing ability was a better predictor of complex propositions and words recorded in notes than other measures. Kiewra and Benton (1988) confirmed that note-takers with lower information-processing ability (probably referring to working memory capacity) perform worse in their note-taking (i.e., writing down fewer notes) because they cannot hold and manipulate as much propositional information as those with higher information-processing ability in their working memory.

More recent studies considered cognitive effort incurred in note-taking. Cognitive effort devoted to actual writing or note-taking is estimated during a dual (e.g., Kellogg, 1994) and triple (e.g., Olive et al., 2002) task. A dual task, for example, includes a primary task and a secondary probe task. A primary task is, for example, to take notes, and a secondary task is to react to tones periodically heard in a random interval, and these tasks are performed simultaneously. The central executive component of working memory functions to coordinate the concurrent tasks, focus attention when each tone is detected, and select a motor response as instructed (Piolat et al., 2005). The secondary task is then separately performed and cognitive effort is estimated by calculating differences in reaction times between the dual task and the secondary task (i.e., dual task (primary task + secondary task) - secondary task). A triple task adds another task such as a verbalisation task where participants label the process that was interrupted by the probe. Studies that used these tasks have shown that note-taking demands more of the central executive than either learning or comprehending alone (e.g., G  rouit et al., 2001; Piolat et al., 1996; Roussey & Piolat, 2003).

In consecutive interpreting, Ilg and Lambert (1996) mentioned that note-taking may in fact interfere with the listening process among untrained interpreters, however, with practices and learning of appropriate consecutive note-taking techniques, note-taking may actually facilitate the listening process. In the field of

language testing, it has been shown that note-taking on a listening test (e.g., IELTS, TOEFL) does not significantly facilitate the test-takers' performance, whereas pushing them to take notes hinders their performance severely (Hale & Courtney, 1994, as cited in Buck, 2001, p. 138). Note-taking may facilitate note-takers' performance on the following comprehension task (Song, 2012); however, it might depend on their language proficiency for the task (e.g., Cushing, 1991; Tsai, 2004). Hence, for the purpose of investigating the effect of note-taking, the current participants were not forced, but 'encouraged' to take notes during the dichotic listening task explained below.

2.8 A contrastive view of Japanese language with English language

I now present features of the Japanese language by contrasting them with those of the English language to highlight the differences faced with and tackled by the current bilingual participants.

There are many differences both in language and writing system. The Japanese and English languages are different not only superficially, that is orthographically (e.g., English: A (deep orthography) vs Japanese: 空 (/sora/, *sky*) (logographic), but also phonologically (English: stress-timed vs Japanese: syllable-timed), typologically (English: SVO vs Japanese: SOV (Greenberg, 1963, p. 77)), and with regards to demonstratives (English: person-focus vs Japanese: situation-focus (Hinds, 1986; Monane & Rogers, 1977, p. 135)).

The English deep orthography represents an ambiguous mapping between letters, speech sounds, and whole-word sounds (e.g., Cossu et al., 1995), so-called letter-sound correspondence rules, having more unusual pronunciations of irregular words than shallow orthographies (e.g., German) and making it more difficult to learn than regular letter-based orthographies (Castles & Nation, 2006). In the Japanese language, there are three types of orthographies: *hiragana*, *katakana*, and *kanji*. Hiragana (e.g., あ) and katakana (e.g., ア) are syllabic scripts each of which represents a sound unit. The third Japanese orthography, kanji is a logographic script

adapted from the Chinese language, and each symbol represents meaning and functions as a morpheme (Chikamatsu et al., 2000). A single kanji character may represent an independent word (e.g., 本 /hon/, *book*) or part of a word (e.g., 本 in 日本 /nihon/, *Japan*). The meaning of each constituent (i.e., a single character) in a kanji word is sometimes less clear or transparent than that of an independent word. Because of the manner in which kanji characters were transferred from the Chinese to the Japanese language over the centuries, a single kanji character may have obtained more than one pronunciation and may be pronounced in several different ways, e.g., depending on where it appears in a sentence. The three orthographies usually appear in a single Japanese sentence because kanji is used for content words, hiragana is used for words that have grammatical functions, and katakana is used for loan words (e.g., 研究チームは米検索大手グーグルの衛星写真を使って探索した洞窟で、195万~178万年前の化石2体を発見した (The research team found 195 million to 178 million-year-old fossils of two bodies in a cave using satellite photos of Google.))

Stress-timed languages including English are those with a rhythm in which stressed syllables tend to recur at regular intervals of time and the length of an utterance depends on the number of stresses rather than the number of syllables. For example, the phrase *BILL WORKS HARD* and the phrase *BILL's been WORKing HARD* take roughly the same amount of time to say in English (Richards et al., 2002, pp. 517-518). Syllable-timed languages such as Japanese and Spanish, are those with a rhythm in which syllables tend to occur at regular intervals of time and the length of an utterance depends on the number of syllables rather than the number of stresses (*ibid.*, p. 532). The Japanese language is also called a *mora-timed* language. The rhythmical principles involved in this categorisation are clearly of considerable importance for the understanding of length, since they determine the timing, and therefore the relative lengths, of parts of the utterance (Fox, 2000, p. 87). The mora is a unit of timing in Japanese, hence the stress cannot fall on the second mora of a long vowel (*ibid.*, p. 98). For example, there are two syllables in a word such as *shimbun* (newspaper [English]), *shim* and *bun*, but Japanese speakers further subdivide it into

four *moras*: *shi*, *m*, *bu* and *n* (Shibatani, 1990, p. 158, as cited in Fox, 2000, pp. 98-99).

Greenberg (1966, as cited in Bialystok & Hakuta, 1994, pp. 35-36) classified world's languages according to correlations between basic features, for example, based on the sequence of subject, verb, and object in a sentence. Word orders commonly found were SVO, SOV, and VSO. VSO languages include Berber, Hebrew, Maori, Masai, and Welsh. SVO languages include English, Finnish, Greek, Guarani, Malay, Swahili, and Yoruba. SOV languages include Japanese, Hindi, Basque, Quechua, and Turkish. Greenberg (1978) and others (Comrie, 1981; Li & Thompson, 1989; Ruhlen, 1987) continued to inspect world's languages and showed distribution and correlations of linguistic characteristics around the world. They demonstrated the cluster of linguistic features that manifestly depends on whether the position of the verb and object in the basic word order of the language is VO (in SVO and VSO languages) or OV (in SOV languages). For instance, VO languages (e.g., English) put relative clauses to the right of a sentence, e.g., the *person* who came to dinner, whereas VO languages (e.g., Japanese) place them to the left, e.g., *ban-gohan* (dinner) *ni* (to) *kita* ([who] came) *hito* (person).

Lastly, Japanese and English are different in terms of what they focus on, whether person or situation, when they interact. This distinction between *situation* focus and *person* focus was proposed by Monane & Rogers (1977). Hinds (1986) elaborated and gave many more examples and developments of different aspects. In his examples, person-focus sentences often seen in English are, 'I have a car.' 'My mother called today,' and 'Has Mr. Brown answered your letter yet?' Situation-focus sentences often uttered by Japanese speakers in the situations above are, '(I) have a car (or even there is a car),' 'There was a phone call (from my mother),' and 'Has a reply come?' As can be seen, English speakers require that a person be mentioned while in Japanese it is preferred that a person not be mentioned, and English speakers put a person into the subject position of the sentence while Japanese speakers tend to avoid even mentioning a specific person (Hinds, 1986, pp. 27-28). Japanese speakers and English speakers will often choose different ways to describe the same situation.

When different ways are selected, the Japanese speaker will almost always be the one to opt for an expression which conveys less information (*ibid.*, p. 29). Although neither study touches on the issue of person focus vs. situation focus in the area of demonstratives, the differences between English and Japanese demonstratives can be delineated in a similar way (Niimura & Hayashi, 1996). In the case of Japanese, in which "domain" is important, the focus is on the situation, whereas in English, FOCUS, or attention, of the speaker can be interpreted as being person focus.

It is notoriously known that Japanese speakers who have learned English as a second language in their adulthood have difficulty in distinguishing between /l/ and /r/, which are in the same phonetic category in Japanese (e.g., MacKain et al., 1981; Miyawaki et al., 1975), although they can learn to produce these phonemes (Flege et al., 1995). Confusion in speech perception among even highly proficient Japanese-French bilingual has been also found, that is they reported an illusory vowel /u/ between consonants, i.e., they perceived /ebzo/ as /ebuzo/ (Dupoux et al., 1999). Phonetic combinations foreign to Japanese such as having no vowels between consonants were apparently resolved by the Japanese listeners by means of assimilating the acoustic input to their native language phonetic rules (Moreno et al., 2008). It appears that speech perception in an L2 is deeply affected by the phonemic structure of the native language (Dehaene-Lambertz et al., 2000).

2.9 Summary and overview of the experiments

Investigations on language switching and language selection have made use of psycholinguistic tasks which cause indirect interference from one language on the other, such as the picture and digit naming tasks where the language to output is cued by a background colour, and naming pictures of objects (e.g. Kroll & Peck, 1998) in which a language to be used is cued by a tone. These tasks were criticised to be indirect measures of degree of bilingualism and proficiency in the four skills in two languages (Cooper et al., 1969; Macnamara, 1969). However, language competition in the brain whilst performing a pure listening activity takes place not consecutively,

but simultaneously, and it is not visible at all like written texts. There needs to be a task that can probe this concurrent language competition and the mechanism of inhibition of another language in bilingual listening comprehension. Giving more direct and abrupt interference or information that has to be ignored would demonstrate more straightforward evidence of language control and inhibition in bilingual speech comprehension, and the task that was considered able to do all these was the dichotic listening (DL) task. Along with an introduction of the new dichotic listening paradigm, a series of experiments presented in this dissertation dealt with interests such as the effects of semantic relatedness and unattended language, ear preference, auditory attentional control (i.e., the effect of ear switching), the effect of note-taking, language switching, cognitive factors (e.g., L2 proficiency and WMC) and experiential factors (e.g., age of L2 acquisition, length of learning, exposure to L2) on bilingual speech comprehension and language control examined in the DL task. An exploratory investigation of the possibility of a new working memory task was also included in the final experiment.

Chapter 3 first presents the new DL task, a bilingual dichotic listening (BDL) task, in Experiment 1 where participants were given their two languages binaurally and asked to attend to their preferred ear and ignore another ear. A half of the BDL stimuli were either semantically related and the other half were unrelated. These pairs of BDL stimuli were heard in the same or different languages. These experimental manipulations made it possible to produce direct and abrupt language interference to explore the bilingual executive control in speech comprehension. Individual differences factors such as cognitive (e.g., L2 proficiency and WMC) and experiential (e.g., age of L2 acquisition, length of learning, exposure to L2) were assessed to determine what would predict most the bilingual executive control capacity in controlling and inhibiting language interference at the meaningful and auditory passage level. Experiment 2 presented in Chapter 4 was conducted in exactly the same way except that the participants were asked to use their *non-preferred* ear to examine the effect of ear preference. The effect of ear preference was investigated this way in order to avoid any complex interpretation if it were included

as another factor (so four-way interactions) in Experiment 1. In Chapter 5, Experiment 3 attempted to delve into bilingual auditory attentional control and inspect whether there would be a right-ear advantage for comprehension and language control at the passage level among bilingual listeners. The REA has been consistently found among monolinguals and bilinguals at the level of smaller linguistic units (e.g., syllables, words, and sentences). Participants in Experiment 3 switched their ears in an alternating order and attended and unattended languages were randomly presented.

Chapter 6 shows replications (Experiments 4, 5, and 6) of the first three studies (Experiments 1, 2, and 3) considering the effect of note-taking and their results. Comparisons were made between Experiments 4 (preferred ear used) and 5 (non-preferred ear used), Experiments 1 (preferred ear used, note-taking not allowed) and 4 (preferred ear used, note-taking encouraged), Experiments 2 (non-preferred ear used, note-taking not allowed) and 5 (non-preferred ear used, note-taking encouraged), and Experiments 3 (ears switched, note-taking not allowed) and 6 (ears switched, note-taking encouraged).

Chapter 7 presents Experiment 7 that was conducted in light of findings from the previous six experiments with a particular focus on bilingual language switching to explore the effect of predictability of language switching, either unpredictable or predictable. Participants in Experiment 7 switched their ears in an alternating order, and attended and unattended languages were presented in a systematic order, unlike Experiment 3 where they were randomly presented. It was also considered necessary to employ a different working memory task to estimate the participants' inhibition component of working memory capacity not only in language inhibition, but also in attentional control.

Finally, Chapter 8 begins with summaries and evaluations of the results in the BDL experiments, followed by descriptions of advantages and limitations of the BDL paradigm. It foresees how the BDL paradigm could be applied with experimental techniques from other disciplines. It then ends with general conclusions

concerning bilingual language and cognitive control that is executed in the real-life listening situation.

CHAPTER 3: LANGUAGE AND COGNITIVE CONTROL IN BILINGUAL SPEECH COMPREHENSION IN THE BILINGUAL DICHOTIC LISTENING (BDL) TASK - EXPERIMENT 1

3.1 Introduction

Most of the studies on bilingual speech comprehension have investigated comprehension at the word-level (e.g., Blumenfeld & Marian, 2007; Chambers & Cooke, 2009; Marian & Spivey, 2003a, 2003b; Spivey & Marian, 1999; Weber & Cutler, 2004), although isolated words are least candidates for exploring language representation (Paradis, 2003). Even when comprehension was investigated at the sentence-level, it is argued that a sentence out of context is nearly always ambiguous, whereas a sentence in a discourse context is rarely ambiguous (Graesser et al., 1997, p. 164). Moreover, in the real-life communication environment, the rich source of information and the large number of behavioural options provide great potential for interference (Ye & Zhou, 2009a).

Under such (pseudo) real-life conditions, the dichotic listening (DL) task has been utilised to investigate the nature of processing natural speech stimuli among both monolinguals and bilinguals (e.g., Asbjørnsen & Hugdahl, 1995; Conway et al., 2001; Filippi et al., 2012). The DL task can also reveal lateral differences in processing a bilingual's two languages (e.g., Asbjørnsen & Helland, 2006), and efficiency of cognitive control in speech comprehension (e.g., Hugdahl, 2003). The current dissertation regards the DL task as the core paradigm for the investigation of the cognitive mechanism of bilingual speech comprehension. Relevant experimental manipulations are integrated into the DL task to achieve this purpose.

In this section, specific topics relevant to the current experimental paradigm are dealt with in each section. Section 3.1.1 gives a brief outline of the effect of semantic features of auditory stimuli in the DL task. Section 3.1.2 briefly summarises how the brain prefers to process speech coming through each ear. This is followed by a summary of the role of one of the most important features in the current dissertation,

WMC, in the DL task (Section 3.1.3). Performing a DL task concurrently entails cognitive control (maintenance of attention and inhibition), processing relevance information between two ears (e.g., physical: (male or female voice, high or low tone), or linguistically related (phonological, semantic, syntactic)), and involves asymmetrical processing efficiency. Hence, these aspects of cognitive processes can be investigated simultaneously, with either linguistic or non-linguistic stimuli. For this reason, the three sections present somewhat overlapping findings from DL studies. Then, Section 3.2 presents hypotheses about the initial investigation, and an illustration of the experimental paradigm I recently developed and the actual experiment (Experiment 1). Finally, Section 3.3 summarises the results and conclusions drawn from the experiment, and shows a proposal for the following experiment.

3.1.1 The effect of semantic relatedness in the DL task

Early dichotic listening studies (e.g., Cherry, 1953) showed there was very little memory for processing the unattended information. Broadbent (1954, 1958) proposed a selective filter that excluded any information that does not have the physical features of the attended message. Nonetheless, Moray (1959) found evidence for semantic processing of unattended information that more processing was in fact performed on the unattended message than was first speculated (see also MacKay, 1973). This gave rise to models of attention (Treisman, 1964) that place selection later in the processing system, or allowed for important information to break through the filter (Styles, 2005, p. 209).

Although it is not a DL study, the effect of unattended speech on perception of visual information was investigated by Salamé and Baddeley (1987). They found that the participants' serial recall for visually presented numbers was interfered with by the unattended speech, in spite of the instruction that the participants had to pay no attention to the speech and even when the speech was in a foreign language or nonsense words. Salamé and Baddeley (1989) further studied the effect of music as

the unattended distractor on the processing of visual stimuli. It was found that the participants were more distracted by the music especially when it was vocal music (i.e., including actual singing of lyrics) than when it was simply instrumental music. With auditory presentations, words seem to have direct access to the phonological store whether or not any articulatory control processes are employed (Styles, 2005, p. 154).

As seen in these DL and irrelevant speech studies and those below, the focus of DL studies was on the investigation of attention, then shifted to hemispheric lateralisation of brain functions. Subsequently, DL studies using speech stimuli became one of the most commonly used paradigms in laterality research (Westerhausen & Hugdahl, 2010, p. 471). The fact that attention is assessed in the DL task becomes important for my later experiments.

3.1.2 Auditory laterality in the DL task

A bilingual's two languages have been suggested to be lateralised differently in their brain. Some studies have shown that a bilingual's L1 is more left lateralised than their L2 (e.g., Obler et al., 1975; Obler & Gjerlow, 1998; Silverberg et al., 1979). It seems that bilingual language lateralisation may depend on L2 proficiency, hence, proficient bilinguals are more left lateralised in their L2 than non-proficient bilinguals (e.g., Lambert, 1993). Lambert (1993) found a significant advantage for the left-to-the-right-hemisphere route for interpretation of this direction (from L2 to L1) among professional simultaneous interpreters (i.e., hearing the source language (L2) in the left ear and checking their orally interpreted L1 in the right ear), suggesting that processing L2 is more efficient through the left ear. The right-to-the-left-hemisphere route was found efficient for interpreting from L1 to L2. The participants were unaware of the effect of their choice of preferred ear on their performance.

Proverbio and Adorni (2011) also recruited simultaneous interpreters and gave them a visual task in two languages where they had to respond to targets, either with

their left or right hand (i.e., right hand response is associated with the left hemisphere, and the left hand with the right hemisphere). A complete left-lateralisation of linguistic functions was found in monolingual students, whereas a complete lack of asymmetry for the interpreters both in L1 and L2 was confirmed. The authors attribute their findings to the interpreters' extensive practice of simultaneous interpreting strategies (e.g., dealing with two input channels; right ear/LH for listening to themselves interpret and left ear/RH for listening to the source language). It could be that as individuals accumulate more experience in processing and switching between their languages, their brain begins to select the most efficient strategy to accurately perceive, interpret, and produce their two languages.

3.1.3 The role of WMC in the DL task

Dichotic listening can not only be seen as an indicator of hemispheric asymmetry but can also be used to study functions of executive and cognitive control (Westerhausen & Hugdahl, 2010, p. 470). As presented above, it is difficult for clinical patients with lower executive control capacity to alter their attention, especially, from the right to the left ear. An fMRI study (Jäncke & Shah, 2002) has shown that processes involved in the DL task are mostly subserved, not by areas for speech processing, but by working memory areas in the frontal lobe. This cognitive demand the DL task casts has been reported especially when attention is directed to the left ear (e.g., Hugdahl et al., 2009).

Conway, Cowan and Bunting (2001) demonstrated that high span participants are better able to attend to the relevant stimuli while inhibiting interference from a highly salient distractor, namely, their names, whereas low span participants reported more frequently hearing their names (low: 60% vs high: 20%) and they are more interfered with by the irrelevant stimuli and make more errors when they hear their names (see also Colflesh & Conway, 2007). Beaman (2004) showed that low-span individuals are more likely to recall auditorily presented irrelevant speech items when the irrelevant speech was semantically related to the visually presented target

stimulus than high-span individuals (see also Sörqvist et al., 2008). These results would suggest that low span participants are unable to effectively attend to the shadowed channel and inhibit irrelevant information at the instance when it is presented, meaning that they are more vulnerable to sudden irrelevant information.

Enhanced executive and cognitive control through extensive experience in switching between languages and suppression of the language not in use have been shown as a bilingual advantage in the inhibition of task-irrelevant information in the DL task with CV syllables (e.g., Hugdahl et al., 2004; Soveri et al., 2011) and sentences (Filippi et al., 2012). The bilingual participants were found to be better able to shift their attention, inhibit task-irrelevant information, and recall more target stimuli than monolingual peers.

It appears that researchers have started to turn their attention to the cognitive mechanism of bilingual speech processing and shown that the bilinguals' executive control and attained L2 proficiency play significant roles in shifting their attention, suppressing irrelevant information (e.g, syllables, words, or language (same as or different from the attended language)), and processing relevant information. These findings lead to the question: would bilingual listeners be able to suppress semantically related and unrelated auditory stimuli that are larger than sentences, i.e., passages, when they are heard in their two languages (one in each ear)? Putting bilingual listeners in this cognitively demanding situation would reveal their executive control capacity in suppressing passage-level auditory stimuli and determine what underpins this ability.

In order to investigate executive control of bilingual speech comprehension, considering all of these suitable experimental manipulations, I suggest a “bilingual dichotic listening (BDL)” task, in which bilinguals are binaurally presented with their two languages, one in each ear while switching between them, and they are heard in passages with low and high semantic relationships between channels. This BDL paradigm would aid our understanding of how bilingual listeners manage to maintain their attention to the relevant language while inhibiting concurrent activation of the irrelevant language in their mind, both of which may well be

semantically related and/or unrelated, then arrive at consistent comprehension throughout a communication.

In the BDL task, comprehension performance was assessed not only in the participants' L2, but also in their L1, in order to see whether semantic information in L2 would interfere with comprehension of L1 as well as the influence of L1 semantic information on L2 comprehension. Languages investigated in this dissertation were vastly different at all levels, i.e., phonologically, syntactically, orthographically, and typologically, as described in Chapter 2.

3.2 Language and cognitive control during comprehension of meaningful passages

The dichotic listening paradigm has been demonstrated as a fine tool to assess executive control and conflict processing in both monolinguals and bilinguals at the phonological, semantic, and syntactic level with syllables, words, and sentences, respectively. Experiment 1 was motivated by these previous findings among bilinguals to further investigate their executive control in speech comprehension of meaningful passages during which they are also encountering competition from related or unrelated passages in the same or the other language from the other channel. In order to further investigate the bilingual's lateralisation for processing their two languages, the participants in Experiment 1 were asked to use their preferred ear (whether it is their left or right ear), and the participants in Experiment 2 were asked to use their non-preferred ear. A cross-experimental analysis between Experiments 1 and 2 was carried out to confirm whether there would be a preferable route for processing meaningful passages in the two languages. Experiment 3 included three experimental manipulations: (1) ear switching; (2) attended language; and (3) unattended language, in order to investigate auditory attentional control in speech comprehension among bilinguals. The following sections describe how bilinguals achieve such an intricate and cognitively demanding task, i.e., the BDL

task, and what cognitive capacity and language experiences are required to accomplish it.

3.2.1 Hypotheses

Four hypotheses are presented below with regard to bilingual speech comprehension of passages with different degrees of semantic relatedness and the role of executive control in conflict processing required to comprehend such passages.

I. Semantically related passages affect comprehension more than semantically unrelated passages.

In the traditional and recent DL studies (e.g., Alho et al., 2003; Berlin et al., 1973; Broadbent, 1958; Cherry, 1953; Cherry & Taylor, 1954; Conway et al., 2001; Moray, 1959; Repp, 1978; Wood & Cowan, 1995), it is found that physical (e.g., male or female voice, unlearned foreign language, different volumes, etc.) and semantic features (relevant or irrelevant) (e.g., Beaman, 2004; MacKay, 1973; Treisman et al., 1974) from the unattended channel can affect perception of information in the attended channel. Then, what would happen if passages were played in two different languages, furthermore, if they were either semantically related or unrelated? The current experiment was inspired by this question and sought to investigate the bilingual executive control in speech comprehension of passages that have different semantic relatedness and are heard in the same or different languages of the participants. It was predicted that interference from the semantically related passage would be harder to inhibit than the semantically unrelated passage regardless of language as the attended and unattended languages.

II. Semantically related L1 interferes more with comprehension of both L1 and L2 than semantically related L2.

III. Semantically unrelated L1 imposes less interference on comprehension of both L1 and L2 than semantically unrelated L2.

According to previous research (e.g., Beaman, 2004; Hugdahl et al., 2004; Sörqvist et al., 2008; Soveri et al., 2011), individuals who are more affected by irrelevant, but semantically *related* speech stimuli are those who have smaller WMC. However, as the auditory stimuli in both attended and unattended channels are almost always in a language of monolinguals or the bilingual's second language, it has not been clear whether bilingual listeners would be also influenced by their other familiar language and even when the attended and unattended languages are inverted (i.e., attended: L1 or L2; unattended: L1 or L2). Nonetheless, information is indeed processed in the unattended channel (e.g., Moray, 1959; Styles, 2005), therefore, it could be that another familiar language in the unattended language can be partially, if not all, processed although required to maintain attention to the other channel. Since when reading or hearing an L2 word, a corresponding L1 lexicon is activated (e.g., Marian & Spivey, 2003a, 2003b; Thierry & Wu, 2007) and L1 is more interfering than L2 (Green, 1998), and listening to L1 words activates L2 candidates (e.g., Marian, et al., 2003), and semantically related information is disruptive (e.g., Beaman, 2004), it was predicted that bilingual listeners would be more influenced by the unattended semantically related L1 than semantically related L2 when they have to listen to L1. Whereas when they listen to L1, as it is their stronger language, it may be easier to block both their weaker L2 and dominant L1, whether related or unrelated.

IV. WMC and L2 proficiency contribute to the efficient processing of one passage while also hearing another that are in the same or different languages and have the same or different semantic information.

Many monolingual DL studies have shown that higher WMC is involved in the ability to inhibit distracting information (e.g., Alho et al., 2003; Asbjørnsen & Hugdahl, 1995; Bryden et al., 1983; Conway & Engle, 1994; Conway et al., 2001;

Engle et al., 1999; Hugdahl, 2003; Hugdahl et al., 2009; Jäncke & Shah, 2002; Macken et al., 2009; Thomsen et al., 2004). Recently, a bilingual advantage in conflict processing when comprehending one language and suppressing the same or another language with the same or different syntactic feature has been shown at a sentence-level (Filippi et al., 2012), which was not investigated, but speculated to be due to their experience in using both languages at work on a daily basis.

Although my dissertation does not intend to show any bilingual advantage compared to monolingual counterparts, it was predicted that bilinguals would also demonstrate their executive control capacity in sustaining their attention to the target language and coping with an interference from another language both when it is semantically related and unrelated, even when the stimuli are a larger linguistic unit, i.e., passages. Since a natural passage includes sentences with different syntactic structures, competition, if at all, would arise from their semantic differences.

3.2.2 Methods

3.2.2.1 Participants²

50 Japanese-English bilinguals (23 females) participated in Experiment 1 in return for a reward. They were categorised as “childhood bilinguals” (Hull & Vaid, 2007). All of them were right-handed, with normal or corrected-to-normal vision and reported no hearing disabilities. During the BDL task, they were asked to use their *preferred* ear as indicated in the earedness questionnaire. These details of the participants are summarised in Table 3.1.

² Caution was taken when collecting participants, hence, a pilot study was conducted in Edinburgh, UK. Japanese-English bilinguals (although a small number of three), who reported themselves as having a good command of both languages, took part in the pilot study. Two of them were born in Japan and studied English while in Japan, then came to Edinburgh for their degree. One of them was born in Japan, but soon taken abroad, and spent much of his time in an English-speaking environment. A Japanese-version RST (Osaka & Osaka, 1994) was used to assess their command of Japanese. However, a performance of the one who lived abroad for many years was severely lower than the rest (he could not even finish the task). He also find it extremely difficult to take the BDL task, too. Hence, although it was first thought necessary to collect participants in the UK, it became apparent that it would be better to collect them in Japan, who would have an intact command of a dominant language and high proficiency in a non-dominant one. In addition, it was found very difficult to get a hold of a good number of balanced Japanese-English bilinguals in the UK.

Table 3.1. *Participants' Gender, Cognitive, and Experiential Characteristics (Experiment 1)*

Gender	English Proficiency	WMC ^b	Age	AoA ^c	LoL ^d
M: 27, F: 23	19.34 (4.02) B2-C1 ^a	2.69 (.720)	21.02 (2.48)	11.26 (2.81)	10.01 (3.25)
Ear Preference ^e	University ^f				
R: 39, L: 11	Tokyo Gakugei University (Tokyo)				

Note. M: Males, F: Females. R: Right, L: Left. Standard deviations are presented in parentheses.

^a Scales indicated in the Common European Framework of References scales (Council of Europe, 2001). Max = 30

^b Max = 5.0

^c Age of L2 acquisition.

^d Length of L2 learning.

^e R: Right, L: Left.

^f University where the participants were collected.

3.2.2.2 *Materials*

Earedness questionnaire

Based on the laterality inventory (Coren et al., 1979), an earedness questionnaire was created in a form appropriate for the current research, that is, earedness for the participants' two languages. Questions used in Coren et al.'s (1979) inventory were such as “Which ear do you use to hear heart beats?”, “Which ear do you use to hear someone behind the door?”, or “Which ear do you use to listen to the transistor radio?” However, these questions tackle uncommon hearing behaviours and do not match situations of the present world (Reiss & Reiss, 1999). Although an ear preference towards the use of a telephone was not often used in an earedness questionnaire, an ear preference for the mobile phone could be a new question item to assess earedness (Ishizu, 2007). Therefore, the following three questions about an ear preference of language on mobile phone were presented to the participants, and they were asked to indicate left or right to each question (see Appendix A.1).

(1) Which ear do you prefer to use on your mobile phone?

- (2) Which ear do you prefer to use on your mobile phone in English?
- (3) Which ear do you prefer to use on your mobile phone in Japanese?

A response to each question was scored as -1, 0, or 1, indicating left, mixed, and right, respectively. The final score indicated whether a participant's ear preference was towards left (negative scores) and right (positive scores). When the final score was 0, the participant was asked to indicate his/her ear preference. Clearly, a valid and reliable earedness questionnaire such as the one by Lambert and Lambert (1985) should have been used to assess the participants' earedness, but, it was thought plausible to use question items that correspond to the use of ears in the present day, and this simple questionnaire should fulfil the current purpose.

Proficiency Test

The vocabulary section in DIALANG (Alderson & Huhta, 2005) was used to estimate the participants' English language proficiency. The test result is shown based on the Common European Framework of Reference (CEFR) scales (Council of Europe, 2001), e.g., C2 (most proficient). The vocabulary section is reliable, short (10-15 minutes), and easy to administer and has been widely used (e.g., Elmer et al., 2010; Escudero, 2007; Grabner et al., 2007; White et al., 2010). There are thirty items and various types of questions such as multiple-choice and sentence-completion items. Although DIALANG is a computer-based test, since test results cannot be saved, the test items were printed and administered on a sheet of A4 paper. To purely assess English proficiency, the instructions for each question item were presented in Japanese (see Appendix A.2), although the question items in the original vocabulary test are shown in English.

Bilingual Dichotic Listening Task

A new experimental paradigm in which bilinguals listen to two languages binaurally and what they hear is semantically related or unrelated between ears, called the bilingual dichotic listening (BDL) task, was developed and administered to

investigate bilinguals' executive control in speech comprehension while switching between their two familiar languages and inhibiting irrelevant speech. This paradigm was based on previous investigations with the dichotic listening paradigm on adult monolinguals and bilinguals (Broadbent & Broadbent, 1990; Colflesh & Conway, 2007; Conway et al., 2001; Filippi et al., 2012; Kane et al., 2001; Kimura, 1961a, 1961b). Thirty-two individually different English passages on a variety of subject matters (e.g., technology, education, science, economics, etc.) were carefully selected from popular news websites (e.g., BBC, The Guardian, CNN, The Wall Street Journal, etc.), whilst analysing their individual readability, consistency of length, and semantic relationships. The average readability ratios of the English passages were 39.28 (Flesch Reading Ease) and 13.22 (Flesch-Kincaid Grade Level). Flesch Reading Ease indicates how easy a passage is to read with scales ranging from 0 (very hard) to 100 (very easy). Flesch-Kincaid Grade Level indicates a grade level in US schools for which a passage is appropriate. They seemed to be relatively difficult and suitable for college students.

Semantically related and unrelated passages were paired according to their semantic relatedness scores (between -1 and +1) on LSA (Latent Semantic Analysis) @ CU Boulder (Landauer et al., 1998). Averaged semantic relatedness scores of related and unrelated passages were 0.78 and 0.26 respectively. The English passages were then translated into Japanese and were analysed for their readability with Obi-2: Readability Analyser of Japanese Passages (Sato et al., 2008). They were reasonably difficult to read for those at a ninth-grade or higher reading level (*Mean*: 6.22 (B9 Scale, 9: most difficult)). 64 (32 English and 32 Japanese) passages were digitally recorded by a bilingual male speaker in the Appleton Tower recording studio at the University of Edinburgh, using a sampling rate of 44.1 kHz with 32 bit quantisation by Audacity 1.3.10-beta on a 13-inch MacBook Pro (Early 2011, Core i7, 2.7 GHz, and 8GB RAM). Recordings were then normalised with respect to root-mean-squared amplitude, and it was made sure that they had an average duration of one minute. Speech rates of the English and Japanese passages were 172.45 words per minute and 411.53 characters per minute respectively.

Two sets of paired passages in eight conditions, sixteen pairs of passages in total for each participant, were prepared depending on whether they were semantically related or unrelated, and whether the language to ignore was the same or different, i.e., four related pairs of passages: English-English, English-Japanese, Japanese-English, and Japanese-Japanese and another four unrelated ones in the same four conditions were made (see Table 3.2 for conditions for passage presentation, and Appendix A.4 for all passages and sentence-completion items). These pairs of passages were counterbalanced in a Latin square design (see Appendix A.3) while maintaining their semantic relationships, but changing their language sets (i.e., the attended and unattended languages). Hence, for example, a pair of the semantically related English-English passages, given to the first participant, were presented with the same attended language but with a different unattended language while maintaining the semantic relationships, i.e., REJ, to the second participant. The unattended Japanese text in the REJ pair was a translation of the unattended English passage in the REE pair as explained earlier. The individual passages that were selected to make semantically related pairs of passages were different from those selected to make semantically unrelated pairs of passages. Therefore, any effect of semantic relatedness would be due not to the different contents in the passages, but to the pure semantic relationships.

Two trials in each of the eight conditions were given to each participant. Each of the audio data pairs was created by mixing two stereo channels, each of which was panned toward either 100% left or 100% right, into one stereo MP3 file. A sentence-completion task with five question items in the language of the attended passage

Table 3.2. *Eight (Four Related and Four Unrelated) Conditions of Passage Presentation*

Related pairs of passages				Unrelated pairs of passages			
REE	REJ	RJE	RJJ	UREE	UREJ	URJE	URJJ

Note. REE: Semantically related English-English, REJ: Semantically related English-Japanese, RJE: Semantically related Japanese-English, RJJ: Semantically related Japanese-Japanese, pairs of passages, respectively. UR represents the semantically unrelated pairs of passages. The language presented to the attended ear is the one shown on the left, so English was attended to, and Japanese was ignored in pairs of REJ and UREJ passages.

followed each auditory stimulus pair for another one minute. A sentence-completion format was employed because it is particularly suitable for testing the understanding of clearly stated information (Buck, 2001, pp. 138-139).

For that purpose, question items in the sentence-completion task accommodate different sentence structures while maintaining the semantics. Hence, for example, if one of the sentences in a passage is, “*Parents and teachers who catch their children lying should not be alarmed,*” a corresponding question item will be “*Teachers don’t need to be when they see their children lying,*” in which *Parents* is omitted, the predicate is earlier than the heard sentence and a different verb (not *catch* but *see*) is used. Comprehension questions were given after presenting the auditory stimuli to provoke abrupt and unpredictable language switches (e.g., Abutalebi et al., 2007) when moving from the previous trial to the next one.

Reading Span Test (ESL)³

As a measure of WMC, the reading span test (RST) (ESL) (Osaka & Osaka, 1992), which is the modified version based on the original RST (Daneman & Carpenter, 1980) and suitable for Japanese speakers of English, was used (see Appendix A.5). In this test, participants were given five sets of sentences that ranged from two- to five-sentence conditions and required to read them aloud while comprehending them. After reading each set, they wrote down words at the end of each sentence. To proceed to the next sentence condition, the participants had to recall three or more sets of words. When they recalled only two sets of words, a score of 0.5 was given and the task was ceased.

³ An ESL version of the RST (Osaka & Osaka, 1992) was adopted as I was interested in comprehension of L2 (English) rather than that of L1 (Japanese) and the roles of WMC in L2 in maintaining attention to L2 while inhibiting L1. Other more general WM tasks such as OSPAN (Turner & Engle, 1989) were not administered because it was considered time-consuming and tiring for the participants and it was unaffordable to recruit participants and ask them to do the remaining tasks spending longer hours. I am well aware that it is crucial to use two or more WM tasks to estimate the participants’ WMC (Conway et al., 2005).

3.2.2.3 *Design*

Experiment 1 had a three-way repeated measures design. The independent variables were semantic relatedness, attended language, and unattended language. Each independent variable had two levels: semantically related or unrelated (semantic relatedness); English or Japanese (attended language); and English and Japanese (unattended language). The dependent variable was the number of questions in a sentence-completion task for each pair of passages the participant answered correctly. Misspellings were counted as errors.

I additionally considered effects of English proficiency, WMC, the age of acquisition (AoA), length of L2 learning (LoL), and amount of exposure to L2 (Exposure), as these individual differences factors have been found to influence bilinguals' language behaviours and associated brain organisations (e.g., Abutalebi, 2008; Indefrey, 2006; Malt & Sloman, 2003; Perani & Abutalebi, 2005; Perani et al., 1998; Wartenburger et al., 2003). AoA, LoL, and Exposure were surveyed in a self-report questionnaire. Relatively detailed profiles of language use in the two languages may explain how daily language usage aids efficient control of the two languages in speech comprehension. In a language history questionnaire for bilinguals such as the Language History Questionnaire (LHQ) (Li et al., 2006) and the Language Experience and Proficiency Questionnaire (LEAP-Q) (Marian et al., 2007) used in the previous studies (e.g., Blumenfeld & Marian, 2011; Whitford & Titone, 2012), questionnaire takers are instructed to indicate percentage of the time they are exposed to each of their languages (*"Please list what percentage of the time you are currently and on average exposed to each language."*). Language skills are indeed interactively used, one or two at a time, hence, it seems reasonable to survey ratios of daily language usage or even frequency (e.g., daily, weekly, monthly, or yearly) (Vingerhoets et al., 2003). However, their method may well make it harder to inspect the degrees of contribution from the exposure to each language skill (i.e., reading, listening, writing, and speaking). Therefore, the current participants were

asked to indicate hours on which they spent daily in each skill⁴. They were analysed for the effects on the dependent variable.

3.2.2.4 Procedure

After signing a consent form, each participant received the earedness questionnaire, the proficiency test, the RST (ESL), the BDL task, and a self-report questionnaire (see Appendix A.6) in consecutive order following the instructions (see Appendix A.7). A short break was inserted between each task. On average, three minutes were spent on the earedness questionnaire and fifteen minutes were spent on the proficiency test.

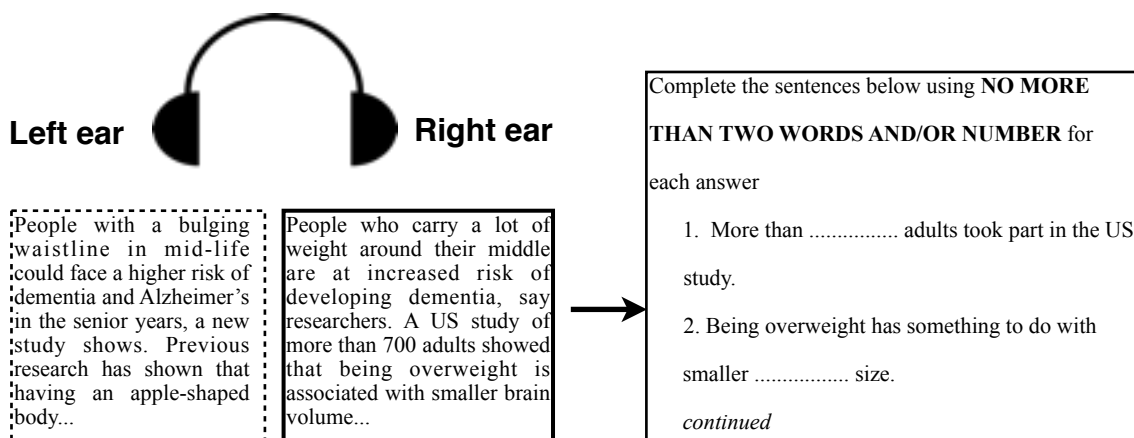
In the RST (ESL), participants read aloud five sets of sentences in two- to five-sentence conditions while remembering the final words of English sentences. They were encouraged to recall the target words in an answer sheet as they appeared in order that a recency effect would not occur. Depending on the number of sets of sentences the participant could recall, the finishing time varied.

In the BDL task, sixteen pairs of passages were presented randomly to each participant after counterbalancing all pairs of passages in a Latin square design, which produced four possible presentation orders. Hence, participants heard sixteen pairs of passages in one of the four orders. Each participant wore a pair of headphones (SONY MDR-V150) and audio stimuli for comprehension were presented to the participant's preferred ear only, that was indicated in the earedness questionnaire based on Coren, Porac, and Duncan (1979) (see Appendix A.1). A three-second interval was inserted between the end of a sentence-completion task and the start of the next auditory stimulus. Keynote was used to present visual (i.e., sentence-completion task questions) and BDL auditory stimuli automatically to

⁴ Although the number of hours spent on each skill reported by the participants was also impressionistic, they were asked to narrow their estimate by remembering how many hours a day they are usually awake and engaged in language activities in each language. They were given the following question that could be a hint for answering the question, "For example, if you sleep for 8 hours a day, you are awake for the rest of 16 hours. During the 16 hours, how many hours or minutes do you spend on each language skill in each language?" They seemed to be unaware of the amount of time they spent on their L1, as it is natural that people do not usually decide how long they use their L1 a day unless necessary, whereas most of them were clear about the amount of time they spend on their L2 as they were learning the language at their university and through self-instruction.

Semantically *related* English-English (REE) passages

Sentence-completion task



Semantically *unrelated* English-Japanese (UREJ)

Sentence-completion task

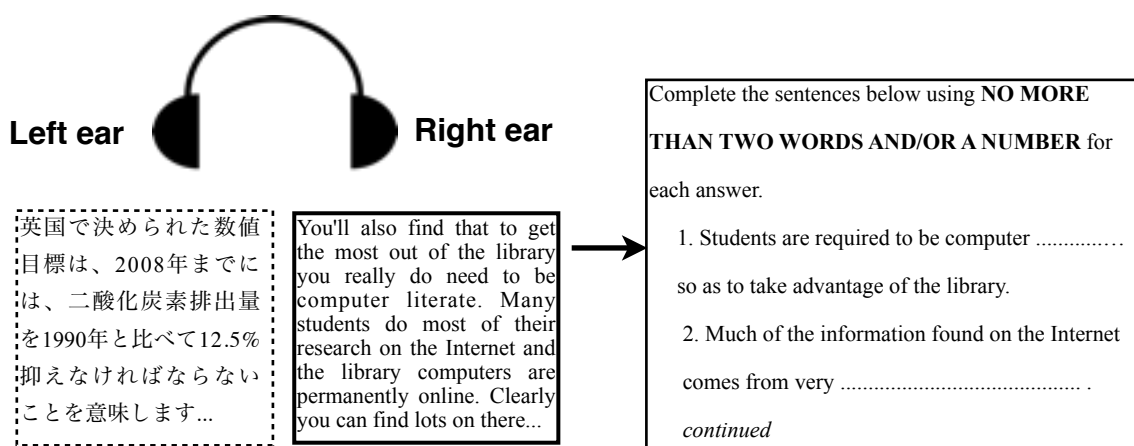


Figure 3.1. An illustration of the experimental paradigm and procedure in the BDL

Note. A passage presented in the attended ear, that is also the preferred ear, is represented with a box with thicker lines, and one in the unattended ear with a box with dotted lines. In an example pair of semantically related REE passages, English is presented to both ears. In an example pair of semantically unrelated UREJ passages, English is played in the attended ear and Japanese in the unattended ear. The semantically unrelated Japanese passage is about ways in which UK is trying to reduce carbon dioxide emissions, hence, it is unrelated to the passage presented to the right ear, which is about how to make the most of library resources. Answers for the sentence-completion tasks are 700 (or *seven hundred*) and *brain* for the semantically related passages, *literate* and *debatable sources* for the semantically unrelated passages.

provide each participant with an equal amount of time for listening to the BDL stimuli and doing the sentence-completion task. Eleven (5 females) out of fifty indicated that they preferred to use their left ear in the earedness questionnaire and thirty-nine (18 females) indicated their right ear as their preferred ear. There was a practice section to get used to the nature and procedure of the BDL task. Overall, it

took approximately thirty-five minutes to complete the BDL task. The whole experiment lasted for at least seventy minutes. Figure 3.1 shows example pairs of passages and the experiment procedure.

3.2.3 Analysis

3.2.3.1 Scoring

The scores of the English proficiency test⁵ (between 0 and 30) and the BDL task (between 0 and 5 for each auditory stimulus) were given depending on the number of questions the participant answered correctly. There were two trials in each condition in the BDL task, and scores in each trial were sent to generalised linear mixed models analyses explained below. The score of the RST (ESL)⁶ (between 2.0 and 5.0) was given depending on the number of sets of words the participant were able to recall and spell correctly.

3.2.3.2 Data analysis

The data were analysed in generalised linear mixed models (GLMM) within the *lme4* package (version 0.999999-2) of R for Mac (version 3.0.1 released on May 16, 2013; Baayen et al., 2008; Bates, 2007; R Development Core Team, 2013). The same model was applied to comprehension of each of eight states (i.e., REE, REJ, RJE, RJJ, UREE, UREJ, URJE, and URJJ) and employed in all seven experiments. Participants were a random effect (random intercepts only), and semantic relatedness (treatment coded: semantically related vs. unrelated; semantically related = baseline), attended language (treatment coded: English vs. Japanese; English = baseline), and unattended language (treatment coded: English vs. Japanese; English = baseline) were fixed effects.

Several individual differences factors were also included as fixed effects to

^{5,6} Participants whose scores were too low in these measures (e.g., lower than 10 in the proficiency test and lower than 2.0 in the RST (ESL)) were declined to take the rest of the tasks.

explain variance due to differences in L2 proficiency (continuous), WMC (continuous), age of L2 acquisition (AoA) (continuous), length of L2 learning (continuous), amount of exposure (Exposure) to L1 and L2 in listening, reading, writing, and speaking (all continuous) and earedness (treatment coded: left vs. right; left = baseline). Most fitted models are presented as the final model after entering these fixed effects into the model and removing non-significant fixed effects and interactions. The simple random-effects structure is adopted because more complex structures will lead to estimation problems (e.g., Slagsvold et al., 2010).

A mixed effects model was used as this enables effective use of all information even from participants who had some missing scores (e.g., Sumathipala et al., 2008), although data from the current experiment included no missing data. A Poisson regression was administered to investigate the relationships between the dependent variable and the fixed effects because it can deal with multiple tokens produced by an individual participant (e.g., Cheng et al., 2008; Gudmestad et al., 2013). For linear mixed models, coefficients describe the amount added to predictions with each one unit covariate change, whereas Poisson and Poisson GLMM coefficients describe the amount multiplied (Atkins et al., 2013, p. 172).

3.2.4 Results

Means of comprehension in each language in each condition are shown in Table 3.3 with standard deviations in parentheses. Results of the GLMM of comprehension of English and Japanese are summarised in Tables 3.4.

Effects of semantic relatedness, attended language and unattended language

Hypothesis I was tested by finding a significant main effect of semantic relatedness. There was a significant main effect of semantic relatedness, $\beta = 0.198$, $SE = 0.082$, $p < .05$, with better comprehension of the semantically unrelated passages than that of semantically related passages ($Mean = 1.603$, $SE = .057$; $Mean = 1.470$,

Table 3.3. *Mean Comprehension Scores of English and Japanese of the Semantically Related and Unrelated Passages in Each Condition (Experiment 1)*⁷

		Attended Language			
		English		Japanese	
		Unattended Language		Unattended Language	
		English	Japanese	English	Japanese
Semantic Relatedness	Related	.44 (.470)	.57 (.615)	2.26 (.797)	2.61 (1.01)
	Unrelated	.68 (.578)	.65 (.455)	2.61 (.797)	2.47 (.944)

Note. $N = 50$. Standard deviations are presented in parentheses.

$SE = .056$, respectively). As expected, a highly significant main effect of attended language, $\beta = 1.447$, $SE = 0.073$, $p < .001$, with better comprehension when the attended language is Japanese than when it is English was found ($Mean = 2.488$, $SE = .081$; $Mean = .585$, $SE = .041$, respectively). There was another barely significant main effect of unattended language, $\beta = 0.164$, $SE = 0.083$, $p < .05$, with better comprehension when the unattended language is Japanese than when it is English ($Mean = 1.575$, $SE = .064$; $Mean = 1.498$, $SE = .052$, respectively). Although 78% (39 out of 50) of the current participants chose their right ear as their preferred (attended) ear and 22% (11 out of 50) chose their left ear as their preferred ear, the effect of attended ear, whether left or right, as the preferred ear was not significant, $\beta = -0.110$, $SE = 0.068$, $p = .1063$. Hence, the results of comprehension in the BDL task in Experiment 1 were not due to the choice of the attended ear.

Hypotheses II and III were tested by comparing comprehension between the four conditions in each attended language and inspecting whether unattended English would be more interfering with comprehension of attended English than unattended

⁷ Mean comprehension scores reported in this table may seem too low for comprehension of spoken passages (*Means*: English: 11.7%, Japanese: 49.76%, overall 30.73%), however, the characteristic of comprehension in the BDL task is different from listening comprehension of one language presented binaurally. Overall accuracy rates in the previous DL task studies are 47.9% (Hugdahl et al., 2008), 41.25% (Hugdahl et al., 2009), and 42.05% (Soveri et al., 2011) in which irrelevant auditory stimuli were presented to the unattended ear. As a one-minute length passage includes a larger amount of linguistic information than syllable pairs used in these studies, although not simply comparable, the ratios of correct responses in the BDL task may be treated as appropriate values that can be sent to later statistical analyses.

Table 3.4. *Coefficients (betas), Standard Errors (SEs), and p Values for Generalised Linear Mixed Models of Listening Comprehension in the BDL Task (Experiment 1)*

Fixed Effects	Comprehension		
	<i>beta</i>	<i>SE</i>	<i>p</i>
(Intercept) ^a	-0.674	0.085	0.0001***
Semantic relatedness (unrelated)	0.198	0.082	0.0161*
Attended language (Japanese)	1.447	0.073	0.0001***
Unattended language (Japanese)	0.164	0.083	0.0481*
Semantic relatedness*Unattended language	-0.217	0.114	0.058(.)
WMC	0.109	0.039	0.0057**
L2 proficiency (residual)	0.019	0.008	0.0256*
Exposure (speaking in L2)	-0.115	0.048	0.0154*
Exposure (speaking in L1)	0.040	0.019	0.0313*
Random Effect	Variance		
Participants	0.0009309		

^a Model assumes baseline is a pair of semantically related passages, with English as the attended language and English as the unattended language.

(.) $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .0001$

Japanese (i.e., REE vs. REJ, and UREE vs. UREJ), whether the semantically related passage would be more interfering than the semantically unrelated passage (i.e., REE vs. UREE, and REJ vs. UREJ), and whether semantically unrelated Japanese would be more interfering than semantically related English (i.e., REE vs. UREJ).

A marginally significant two-way interaction was found between semantic relatedness and unattended language, $\beta = -0.217$, $SE = 0.114$, $p = .058$ (see Figure 3.2). This shows an unexpected negative tendency where comprehension of

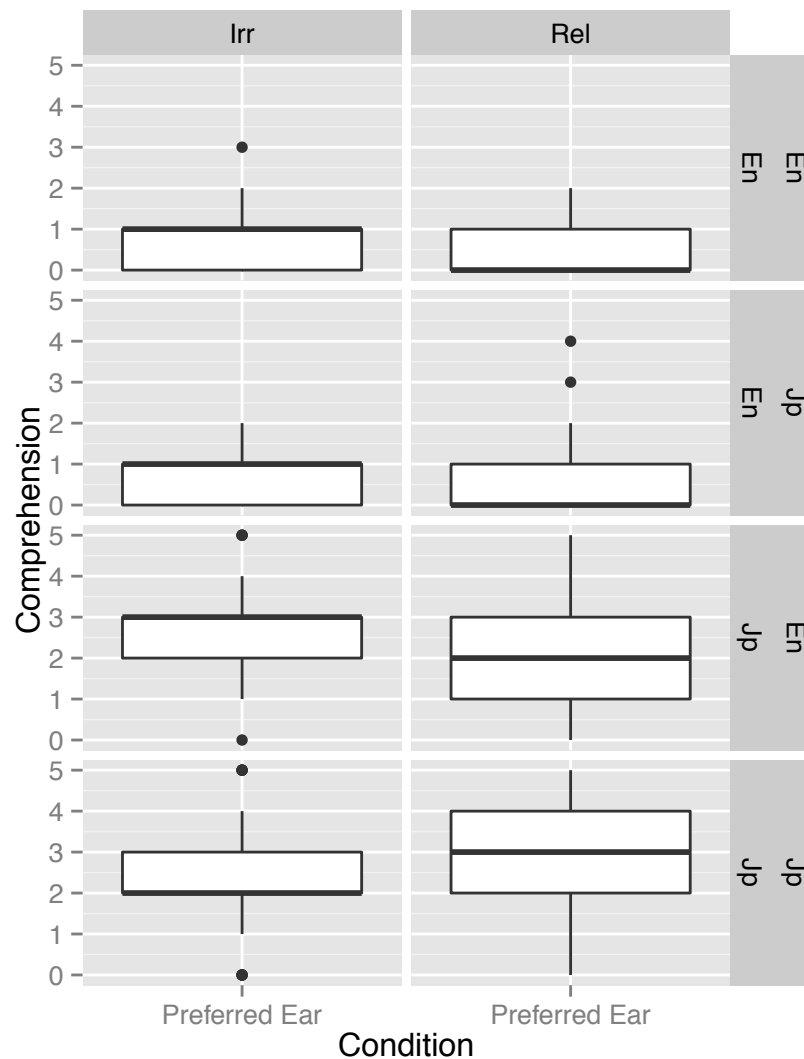


Figure 3.2. Boxplots showing the interquartile ranges of comprehension scores for conditions of the semantically related passages (REE, REJ, RJE, and RJJ) and the semantically unrelated passages (UREE, UREJ, URJE, and URJJ) (Experiment 1). Rel refers to semantically related and Irr to semantically unrelated. En: English; Jp: Japanese. The first label in the row name refers to the attended languages and the second label in the row name refers to the unattended languages. Condition denotes that the participants used their preferred ear. Medians are presented with the thick horizontal bars. Dots in the figure represent data points that are outside of the 95% confidence interval, which is shown by the vertical lines extending beyond the first and third quartile hinges.

semantically unrelated passages when the unattended language is Japanese slightly decreases, although not statistically significant. It is unexpected because the current participants have shown overall better comprehension of the semantically unrelated

passages than the semantically related passages ($\beta = 0.198$, $SE = 0.082$, $p < .05$, $Mean = 1.603$, $SE = .057$; $Mean = 1.470$, $SE = .056$, respectively), and better comprehension with Japanese as the unattended language than with English as the unattended language ($\beta = 0.164$, $SE = 0.083$, $p < .05$, $Mean = 1.575$, $SE = .064$; $Mean = 1.498$, $SE = .052$, respectively). As the two-way interaction was not significant, no further comparisons and interpretations are made. No other two- or three-way interactions reached significance (semantic relatedness*attended language, $\beta = -0.291$, $SE = 0.214$, $p = .1729$, attended language*unattended language, $\beta = -0.115$, $SE = 0.220$, $p = .6020$, and semantic relatedness*attended language*unattended language, $\beta = 0.105$, $SE = 0.294$, $p = .7215$).

Individual differences factors

Hypothesis IV was tested in a GLMM with Poisson error distribution by finding significant main effects of continuous variables on the dependent variable. Results of the GLMM with Poisson error distribution where comprehension of each state (i.e., REE, REJ, RJE, RJJ, UREE, UREJ, URJE, and URJJ) is the dependent variable, WMC, L2 proficiency, Exposure (speaking in L2), and Exposure (speaking in L1) are fixed factors, and participants is the random effect, are shown in Table 3.4. Effects of the other individual differences factors (AoA, LoL, Exposure (reading in L2), Exposure (writing in L2), Exposure (listening in L1), Exposure (reading in L1), and Exposure (writing in L1)) were found to be non-significant, hence, they were not included in the final model.

Overall comprehension of both L1 and L2 was found to be ascribable to the degrees of WMC ($\beta = 0.109$, $SE = 0.039$, $p < .01$) and L2 proficiency ($\beta = 0.019$, $SE = 0.008$, $p < .05$), with WMC contributing more to comprehension. Presumably the most relevant experiential factor, Exposure (listening in L2) ($Mean = 1.15$ hours, $SD = .95$) was not found to predict the dependent variable, $\beta = 0.048$, $SE = 0.037$, $p = .1937$, hence it was not included in the final model. The amount of speaking in L1 ($\beta = 0.040$, $SE = 0.019$, $p < .05$; $Mean = 3.53$ hours, $SD = 1.56$,

18.65% of the total amount of time in L1 and L2) was positively related to comprehension, and the amount of speaking in L2 ($\beta = -0.115$, $SE = 0.048$, $p < .05$; $Mean = .51$ hours, $SD = .72$, 2.69% of the total amount of time in L1 and L2) was negatively related to comprehension. A significant interaction was found between attended language and L2 proficiency, $\beta = -0.056$, $SE = 0.021$, $p < .01$, suggesting that L2 proficiency is more related to comprehension of English than that of Japanese. The rest of the experiential factors and exposures to each language were also non-significant, hence, they were not included in the final model.

3.2.5 Discussion

3.2.5.1 Influences from semantic relatedness and unattended language on bilingual speech processing

In the new DL paradigm with a larger linguistic unit that entails direct and abrupt language interference, Experiment 1 has revealed that bilingual listeners experience more interference from unattended semantically related passages than unattended semantically unrelated ones, whether the attended language is L1 or L2 and whether the unattended language is L1 or L2 (see Table 3.4). These results support Hypothesis I that in general semantically related passages hinder comprehension more than semantically unrelated ones. Of particular importance is that the BDL task has contributed to the current finding that bilingual listeners recognise semantic differences between binaurally presented *passages* and semantically related information has a stronger interfering effect than semantically unrelated information. These findings are consistent with previous DL studies with syllables, words, and sentences (e.g., Beaman, 2004; Filippi et al., 2012; Hugdahl et al., 2004; Sörqvist et al., 2008; Soveri et al., 2011), where bilinguals were found to be efficient in blocking irrelevant linguistic information of these kinds.

Comprehension of Japanese, the participants' dominant language, was significantly better than that of English, their non-dominant language, which is unarguable and plausible. The positive effect of Japanese as the unattended language

on comprehension, although barely significant ($p = .0481$), is in fact interesting and worth some discussion.

This finding is literally the total opposite from previous studies (e.g., Blumenfeld & Marian, 2007; de Groot, 2011; Marian & Spivey, 2003a, 2003b; Spivey & Marian, 1999; Weber & Cutler, 2004) where they found that L2 was interrupted by L1 and L1 was not interrupted by L2, and that speech perception in the more dominant L1 was unaffected by less proficient L2, but not the other way around. It also contradicts with the theory of inhibitory control (Green, 1998) that L1 is harder to inhibit than L2 when attention is paid to L2.

These differential influences from L1 on comprehension may derive from the different experimental paradigms, although competitors are simultaneously presented to the participants in both paradigms. In the visual-world paradigm (e.g., Marian & Spivey, 2003a, 2003b; Spivey & Marian, 1999), both the target and competitor are visually presented (auditory stimuli in these studies did not receive any intrusion from other visual and auditory information), whereas in the BDL task both target and competitor are presented auditorily, hence, the target auditory stimulus directly undergoes an interference from the competitor auditory stimulus.

Based on the assumption by Stanton et al. (1992) that auditory information is more attention-directing than visual information, Latorella (1998) investigated the influence of interruptions of the same-modality (i.e., visual-visual and auditory-auditory) and cross-modality (i.e., visual-auditory and auditory-visual) on performance among airline pilots in a fixed-base simulator similar to a Boeing 737 aircraft. The visual target task was to obtain information from the Flight Management System and the auditory task was to listen to an automated terminal information service recording. Interruptions were air traffic control (ATC) instructions and they were presented either visually or auditorily.

The results demonstrated that the influence of the auditory interruptions on visual tasks was approximately three times weaker and the influence of the visual interruptions on visual tasks was 4.5 times weaker than the influence of the auditory interruptions on the auditory tasks (see also Rees et al., 2001). Although the length

and speed of the ATC instructions are not described in Latorella (1998), the ATC instructions are usually given at 235 words per minute (wpm) (Taylor et al., 2005), that is much faster than the normal speaking rate of 180 wpm (Uchanski, 2005). In this kind of practical situation with actual materials, coping with competition from an auditory stimulus when the target task is also auditory seems to be more cognitively demanding than when the target is visual, even when these stimuli are presented in L1.

Thus, the visual target task in the visual-world paradigm at the word-level with an auditory competitor may be much easier than the BDL task (in fact, the accuracy rates in the visual-world paradigm are higher than 90% in all conditions), that is, it is easier to inhibit visual competitors when engaged in a visual task, whether they have competing features from L1 or L2. Therefore, the magnitude of competition between the visual target stimulus and competing visual stimulus in the visual-world paradigm cannot be compatible with that in the BDL task, which might have caused the contrasting interference tendencies from the unattended language.

In the current BDL task, it was found, on the contrary, that comprehension was better, regardless of semantic relationships between channels and whether the attended language was L1 or L2, when the unattended language was Japanese than when it was English. This would suggest that the dominant language as the unattended language in actuality less interrupts the processing of the attended language, whether it is semantically related or unrelated, and L1 or L2, than the unattended English, and that it rather enhances the maintenance of attention to the target language. These findings reject both Hypothesis II that semantically related L1 puts more influence on comprehension of both L1 and L2 than semantically related L2, and Hypothesis III that semantically unrelated L1 imposes less interference on comprehension of both L1 and L2 than semantically unrelated L2. A clearer effect of Japanese as the unattended language is expected to be found in the following experiments (Experiments 2, 4, and 5), and further discussion is given once comparisons are made between these experiments.

3.2.5.2 Cognitive underpinnings for bilingual speech comprehension

Factors that may help sustain bilingual speech comprehension that invariably involves language control and executive control in maintenance of attention to one language and inhibition of another were examined by considering effects of continuous variables such as WMC, L2 proficiency, AoA, LoL, Exposures (reading, listening, writing, and speaking) in L1 and L2. A GLMM with Poisson error distribution revealed that effectively preserving attention to the target language and resolving conflicts of cross-linguistic and semantic components from both L1 and L2 heard in the unattended channel requires both high L2 proficiency and WMC, which supports Hypothesis IV. The current results are consistent with those of previous studies with the DL paradigm where bilinguals' higher L2 proficiency was found to well predict the ability to resist interferences from both of their languages at the sentence-level (Filippi et al., 2012), and bilinguals with high WMC were found to be better able to focus their attention to the target stimuli and inhibit task-irrelevant stimuli than those with low WMC (e.g., Soveri et al., 2011). It has to be noted that the current results show that L2 proficiency is selectively related to comprehension of L2 than that of L1, but WMC is non-selectively related to comprehension of both languages as the effect of WMC by itself was significant and interactions between WMC and semantic relatedness, attended language, and unattended language were non-significant.

The current results in the new BDL paradigm may provide support for the view that the BDL task can create a condition to investigate the role of WMC in maintenance of attention to one language and conflict resolution from another linguistic stimulus as large as a passage among bilingual listeners. Although monolinguals were not included as a control group in the current experiment, the significant roles of L2 proficiency and WMC found in the BDL task may also provide supporting evidence for the bilingual advantage in tasks requiring effective inhibition of task-irrelevant cues (i.e., the unattended language (L1 or L2) with same or different semantic relatedness states in this experiment) (e.g., Bialystok, 2001;

Bialystok et al., 2008; Bialystok et al., 2004; Costa et al., 2008; Craik & Bialystok, 2006; Emmorey et al., 2008; Prior & MacWhinney, 2010).

The AoA and LoL were not found to provide any explanations for better executive control in speech comprehension among the current participants. It may be because the AoA that has been shown to alter bilinguals' neurocognitive organisation of the brain and consequent language behaviours is before 6 (e.g., Hull & Vaid, 2007; Vaid & Genesee, 1980; Vaid & Hull, 2002), whereas the AoA among the current participants was 11 ($Mean = 11.26$, $SD = 2.81$). Nevertheless, Perani et al. (1998) found that attained L2 proficiency rather than the AoA (early: before 4; late: after 10) is a better predictor for the brain organisation of language comprehension (Perani et al.'s (1998) investigation was on listening comprehension) (see also Abutalebi et al., 2005 and Abutalebi, 2008). The AoA has been found to selectively influence the bilingual brain organisation of syntactic processing (e.g., Wartenburger et al., 2003; Weber-Fox & Neville, 1996). Rather than L2 proficiency, the LoL (an extensive L2 immersion environment) was found to be a better predictor for native-like language behaviours (e.g., Malt & Sloman, 2003), which would mean that the LoL might not be a significant contributing factor unless one uses L2 very frequently. Hence, it may be plausible that the effects of the AoA and LoL were not significant, and that of L2 proficiency was.

The amount of L2 listening ($Mean = 1.15$ hours, $SD = .95$) was, unexpectedly, not found to explain the dependent variable, whereas the amount of L1 speaking was ($Mean = 3.53$ hours, $SD = 1.56$), and the amount of L2 speaking was negatively contributing to comprehension ($Mean = .51$ hours, $SD = .72$). On average, the current participants were exposed to their two languages for 18.93 hours a day (this number includes overlapping amounts of listening while reading and reading while writing, and so forth). Previous studies show that more than 30% of exposure to L2 is a stronger determinant of both L1 and L2 processing than lower exposure (lower than 30%) (e.g., Whitford & Titone, 2012). During the 18.93 hours, the current participants spent only 6.08% on L2 listening and 2.69% on L2 speaking, which explains why the amount of L2 listening was not a significant predictor for the

dependent variable and the amount of L2 speaking was negatively contributing. On the contrary, 18.65% was spent on L1 speaking which necessarily includes listening in L1, hence, its effect was significant. The largest amount of time was spent on L1 listening (38.35%), which was not a significant predictor ($\beta = -0.006$, $SE = 0.009$, $p = .5395$). It would suggest that unbalanced ratios of exposure to each skill may reversely hinder listening performance in both languages.

3.3 Summary and Conclusions

Experiment 1 attempted to investigate how semantic and linguistic features in the unattended channel influence speech comprehension in the attended channel, and the roles of executive control and experiential factors in conflict resolution in the presence of task-irrelevant information in the newly developed BDL task. The current results have shown that the semantically unrelated passages are better comprehended, meaning that semantic information, whether related or unrelated, is indeed processed and not totally blocked (e.g., Moray, 1959; Styles, 2005; Treisman et al., 1974), even when the auditory stimuli are both meaningful passages as long as one minute and, furthermore, in two languages, and that the semantic unrelatedness is utilised to maintain attention to the target channel.

Japanese as the unattended language, whether it is semantically related or unrelated, in fact helps the bilingual listener to inhibit the passage in Japanese and focus her attention to the attended language, whether it is L1 or L2. This is contrary to the theory of inhibitory control (Green, 1998) that maintains that L1 is more interfering than L2, which needs further explorations. It would be required to investigate how the mechanism of the bilingual's inhibitory control works when the bilingual is engaged in all four language skills (i.e., listening, reading, speaking, and writing), and not to draw any conclusion regarding bilingual inhibitory control from studies on only one language skill.

Comprehension of the dominant language is unquestionably better than that of the non-dominant language regardless of the semantic relationships between channels, and whether the unattended language is L1 or L2.

Consistent results with regard to the significant roles of L2 proficiency (e.g., Filippi et al., 2012) and WMC (e.g., Engle & Kane, 2004) in maintenance of attention to one language and inhibition of another, task-irrelevant language, have been found in the BDL task. This would suggest that the BDL task can be used as an experimental paradigm to investigate executive control (e.g., Conway et al., 2001) and language control (e.g., Bialystok, 2009) in bilingual speech comprehension, i.e., *comprehension of meaningful and auditorily presented passages* (emphasis added). The BDL task seems to be a cognitively demanding task which Mercier et al. (2013) suggest be used to explore bilingual language processing and the development of the executive control mechanism driven by the consistent recruitment of domain-general WMC in managing their two languages.

The following experiments further explore the cognitive mechanism of bilingual speech comprehension in the BDL task by adding a simple, but logical experimental manipulation such as ear preference, ear switching, language switching, and note-taking. Cross-experimental analyses are conducted to investigate effects of these manipulations between Experiments 1 (preferred ear used, note-taking not allowed) and 2 (non-preferred ear used, note-taking not allowed), Experiments 4 (preferred ear used, note-taking encouraged) and 5 (non-preferred ear used, note-taking encouraged), Experiments 3 (ear switching, note-taking not allowed) and 6 (ear switching, note-taking encouraged), Experiments 1 (preferred ear used, note-taking not allowed) and 4 (preferred ear used, note-taking encouraged), Experiments 2 (non-preferred ear used, note-taking not allowed) and 5 (non-preferred ear used, note-taking encouraged), and Experiments 6 (ear switching, language randomly switched, note-taking encouraged) and 7 (ear switching, language switching alternated, note-taking encouraged). The results are expected to demonstrate practical traits of the cognitive mechanism of bilingual speech comprehension in the real-life situation.

CHAPTER 4: LATERAL PREFERENCE IN SPEECH COMPREHENSION - EXPERIMENT 2

4.1 The role of lateral preference in speech comprehension

Among professional simultaneous interpreters, it has been found that there are favourable routes, one for interpreting from L2 to L1 (left ear) and another for interpreting from L1 to L2 (right ear) (e.g., Fabbro et al., 1991; Lambert, 1993; Rinne et al., 2000). Fabbro, Gran, and Gran (1991) showed in a DL study a right-ear advantage among professional interpreters for processing semantic information in L1 and a left-ear advantage for processing semantic information in L2. In processing syntactic information, they showed a reversed tendency, i.e., a right-ear advantage for L1 and a left-ear advantage for L2.

Rinne et al.'s (2000) study with a PET among simultaneous interpreters demonstrated a stronger involvement of the DLPFC when interpreting from L1 to L2 than from L2 to L1, thus showing the L1-to-L2 direction to be a more demanding task. Several other studies have also shown that simultaneous interpreters show a smaller left lateralisation for processing linguistic stimuli than bilinguals who are not interpreters (e.g., Green et al., 1990; Proverbio & Adorni, 2011; Proverbio et al., 2009). Simultaneous interpreters also show a greater involvement of their right hemisphere, indicating that they depend on attentional and pragmatic strategies for which the right hemisphere is responsible (e.g., Fabbro & Gran, 1997; Paradis, 2003; 2009).

On these accounts, Experiment 2 was conducted to investigate whether bilingual listeners would also show a better route (i.e., an ear-to-hemisphere route) for comprehending meaningful passages that are larger than syllables and contain interactive interferences from the two languages and semantic relationships in the BDL task.

Hence, the primary purpose of conducting Experiment 2 was to replicate Experiment 1 and find whether the effects of semantic relatedness, attended

language, and unattended language would depend on ear (i.e., preferred or non-preferred). The secondary purpose was to compare results of Experiment 2 with those of Experiment 1 to investigate whether there would be a main effect of ear preference in language control and inhibition in bilingual speech comprehension. The third purpose, same as for Experiment 1, was to explore whether there would be equivalent main effects of semantic relatedness, attended language and unattended language in the BDL task, and relationships between comprehension and individual differences factors such as L2 proficiency, WMC, AoA, LoL, and Exposure to L1 and L2, when the unfavourable speech processing route had to be used during the BDL task.

4.1.1 Methods

The methods (materials, design, procedure, and data analysis) employed in Experiment 2 were exactly the same as those in Experiment 1 except that the participants were different individuals from those in Experiment 1. They were required to use their *non-preferred* ear in the BDL task.

4.1.2 Participants

50 Japanese-English bilinguals (43 females)⁸ were gathered in return for a reward. All of them were right-handed, with normal or corrected-to-normal vision and reported no hearing disabilities. During the BDL task, they were asked to use their *non-preferred* ear, the opposite ear indicated in the earedness questionnaire. The details of the participants are summarised in Table 4.1.

⁸ In the Bergen DL task with 1,018 participants (483 males, 535 females), it was revealed that there was no gender difference in their performance from both of their ears. Both groups showed an REA and no interaction with handedness or age was confirmed (Hugdahl, 2003). In addition, the effect of gender was not the point of interest in the current dissertation, hence, it was not included in the data analyses.

Table 4.1. *Participants' Gender, Cognitive, and Experiential Characteristics (Experiment 2)*

Gender	English Proficiency	WMC^b	Age	AoA^c	LoL^d
M: 7, F: 43	17.36 (3.49) B2-C1 ^a	2.79 (.678)	19.94 (1.49)	10.74 (3.37)	9.34 (3.22)
Ear Preference^e	Universities^f				
R: 34, L: 16	Tokyo Gakugei University (Tokyo), Dokkyo University (Saitama), and Hokkaido University of Education, Hakodate (Hokkaido)				

Note. M: Males, F: Females. R: Right, L: Left. Standard deviations are presented in parentheses.

^a Scales indicated in the Common European Framework of References scales (Council of Europe, 2001). Max = 30

^b Max = 5.0

^c Age of L2 acquisition.

^d Length of L2 learning.

^e R: Right, L: Left.

^f Universities where the participants were collected.

4.1.3 Results

Means of comprehension in each language in each condition are shown in Table 4.2 with standard deviations in parentheses. Results of the GLMM of comprehension of English and Japanese are summarised in Tables 4.3 and 4.4 (see Appendix B.1), respectively. As the principal purpose of Experiment 2 was to replicate Experiment 1 and find whether the effects of semantic relatedness, attended language, and unattended language would depend on ear (i.e., preferred or non-preferred) or not, this section presents results with brief discussion.

Effects of semantic relatedness, attended language and unattended language

The effect of semantic relatedness was not significant, $\beta = 0.154$, $SE = 0.197$, $p = .4334$, suggesting that semantic information from the unattended channel did not

Table 4.2. *Mean Comprehension Scores of English and Japanese of the Semantically Related and Unrelated Passages in Each Condition (Experiment 2)*

		Attended Language			
		English		Japanese	
		Unattended Language		Unattended Language	
		English	Japanese	English	Japanese
Semantic Relatedness	Related	.48 (.534)	.62 (.435)	2.45 (.797)	2.26 (.864)
	Unrelated	.56 (.568)	.35 (.407)	2.48 (.749)	2.41 (.800)

Note. $N = 50$. Standard deviations are presented in parentheses.

significantly influence comprehension of the attended language (Related passages: $Mean = 1.453$, $SE = .057$; Unrelated passages: $Mean = 1.450$, $SE = .049$). The effect of unattended language was also non-significant, $beta = 0.256$, $SE = 0.192$, $p = .1833$, indicating that not only semantic information but also language information (L1 or L2) did not influence comprehension in the attended ear (Unattended Japanese: $Mean = 1.410$, $SE = .051$; Unattended English: $Mean = 1.493$, $SE = .054$).

As expected, the effect of attended language was significant, suggesting better comprehension when the attended language is Japanese than when it is English, $beta = 1.564$, $SE = 0.078$, $p < .001$ (Japanese: $Mean = 2.400$, $SE = .078$; English: $Mean = 0.503$, $SE = .043$). Although 68% (34 out of 50) of the current participants chose their left ear as their non-preferred (attended) ear and 32% (16 out of 50) chose their right ear as their non-preferred ear, the effect of attended ear, whether left or right, as the non-preferred ear was not significant, $beta = 0.086$, $SE = 0.063$, $p = .1766$. Hence, the results of comprehension in the BDL task were not due to the choice of the attended ear.

A two-way interaction between semantic relatedness and unattended language was found to be significant, $beta = -0.726$, $SE = 0.289$, $p < .05$. This interaction results from the greater decreases in comprehension when the unattended language changes its semantic relationships with the attended language (i.e., from REJ to

Table 4.3. *Coefficients (betas), Standard Errors (SEs), and p Values for Generalised Linear Mixed Models of Listening Comprehension in the BDL Task*

Fixed Effects	Comprehension		
	<i>beta</i>	<i>SE</i>	<i>p</i>
(Intercept) ^a	-0.737	0.144	0.0001***
Semantic relatedness (unrelated)	0.154	0.197	0.4334 (ns)
Attended language (Japanese)	1.630	0.158	0.0001***
Unattended language (Japanese)	0.256	0.192	0.1833 (ns)
Semantic relatedness*Attended language	-0.142	0.216	0.5118 (ns)
Semantic relatedness*Unattended language	-0.726	0.289	0.0120*
Attended language *Unattended language	-0.337	0.213	0.1145 (ns)
Semantic relatedness*Attended language* Unattended language	0.778	0.316	0.0140*
WMC	0.087	0.044	0.0498*
L2 proficiency	0.004	0.009	0.6686 (ns)
Random Effect	Variance		
Participants	0.001408		

^a Model assumes baseline is a pair of semantically related passages, with English as the attended language and English as the unattended language.

* $p < .05$, *** $p < .0001$

UREJ, *Means* = .62, .35, respectively), and when the unattended language changes from English to Japanese (i.e., from UREE to UREJ, *Means* = .56, .35, respectively) than when the attended Japanese experiences these changes. Further, the two-way interaction was qualified by a significant three-way interaction between semantic relatedness, attended language, and unattended language, $\beta = 0.778$, $SE = 0.316$, $p < .05$. Hence, the three-way interaction results from the slightly better comprehension when the unattended language was English than when it was

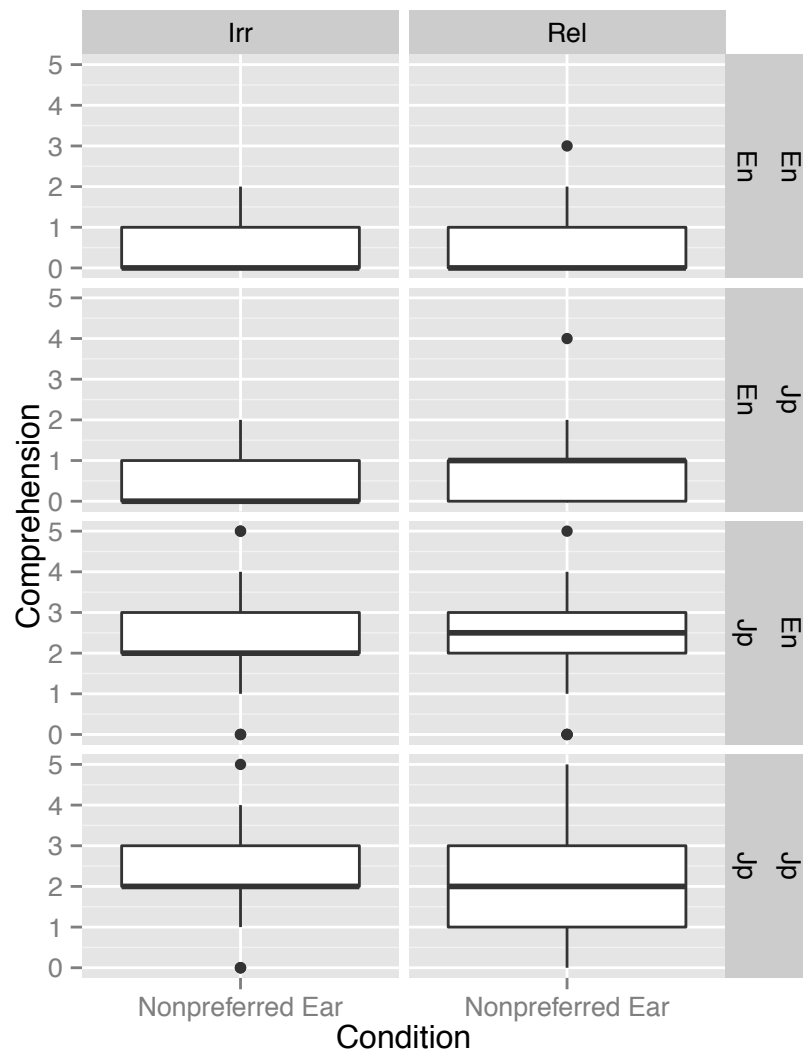


Figure 4.1. Boxplots showing the interquartile ranges of comprehension scores for conditions of the semantically related passages (REE, REJ, RJE, and RJJ) and the semantically unrelated passages (UREE, UREJ, URJE, and URJJ) (Experiment 2). *Rel* refers to semantically related and *Irr* to semantically unrelated. *En*: English; *Jp*: Japanese. The first label in the row name refers to the attended languages and the second label in the row name refers to the unattended languages. Condition denotes that the participants used their preferred ear. Medians are presented with the thick horizontal bars. Dots in the figure represent data points that are outside of the 95% confidence interval, which is shown by the vertical lines extending beyond the first and third quartile hinges.

Japanese as shown earlier. Other two-way interactions between semantic relatedness and attended language ($\beta = -0.142$, $SE = 0.216$, $p = .5118$), and between attended language and unattended language ($\beta = -0.337$, $SE = 0.213$, $p = .1145$) did not reach significance (see Figure 4.1).

To identify what caused the significant three-way interaction, pairwise comparisons between the eight conditions (i.e., REE, REJ, RJE, RJJ, UREE, UREJ, URJE, and URJJ) were conducted separately for each condition and the other conditions (see Table 4.4 in Appendix B.1). These tests can be considered as post hoc comparisons conducted only after significant interactions between semantic relatedness, attended language, and unattended language were found (for this post hoc analysis, see Curéa et al., 2012). These comparisons were carried out using GLMMs in which the same fixed and random effects for the GLMMs used for the final model were included.

Comprehension of Japanese, the participants' dominant language, was not influenced by semantic relatedness of the unattended language, whether it was L1 or L2, which was confirmed in the pairwise comparisons (see Table 4.4 in Appendix B.1). This would show that it is effortless to maintain attention to one's native language and ignore information from the other channel regardless of its linguistic characteristics.

Rather unexpected behaviours were found in comprehension of English. There were no comprehension differences between REE (*Mean*: .48) and REJ (*Mean*: .62) ($\beta = 0.256$, $SE = 0.192$, $p = .1833$), between REE and UREE (*Mean*: .56) ($\beta = 0.154$, $SE = 0.197$, $p = .4333$), and between REE and UREJ (*Mean*: .35) ($\beta = -0.316$, $SE = 0.222$, $p = .1554$), indicating that the changes in semantic relatedness and unattended language do not bring about interference on comprehension of the attended English.

The negative effect of semantic relatedness was represented in comprehension differences when the unattended language was Japanese between REJ and UREJ (UREJ (*Mean*: .35) < REJ (*Mean*: .62), $\beta = -0.572$, $SE = 0.211$, $p < .01$), with higher comprehension in REJ. Between UREE and UREJ, unexpectedly, the native language was found to be more interfering than the second language (UREJ (*Mean*: .35) < UREE (*Mean*: .56), $\beta = -0.470$, $SE = 0.216$, $p < .05$), with higher comprehension in UREE.

Individual differences factors

Overall comprehension of both L1 and L2 was found to be ascribable to the degrees of WMC, $\beta = 0.087$, $SE = 0.044$, $p < .05$, but not to L2 proficiency, $\beta = 0.004$, $SE = 0.009$, $p = .6686$. The effect of the amount of listening in L2 remained non-significant ($\beta = -0.009$, $SE = 0.026$, $p = .7304$, $Mean = .99$ hours, $SD = 1.23$, 4.93% of the total amount of time in L1 and L2). The rest of the experiential factors and exposures to each language were also non-significant, hence, they were not included in the final model.

The next section presents a cross-experimental comparison between Experiments 1 and 2.

4.2 Cross-experimental analysis between Experiments 1 and 2

The effect of ear preference (i.e., lateralisation), whether left or right, for processing bilinguals' two languages when their attention is directed to one language and there is another language (either L1 or L2) in the other ear, and when these languages are semantically related and unrelated, was investigated in the same GLMM in which the effect of ear preference was included as a fixed effect.

4.2.1 Results and Discussion

Results of the GLMM are shown in Table 4.5. Fixed effects and interactions that were found to be significant are shown in the table, but they are not discussed extensively as the main interest is to find the significance of the effect of ear preference.

Table 4.5. *Coefficients (betas), Standard Errors (SEs), and p Values for Generalised Linear Mixed Models of Listening Comprehension in the BDL Task (Experiments 1 and 2)*

Fixed Effects	Comprehension		
	<i>beta</i>	<i>SE</i>	<i>p</i>
(Intercept) ^a	-0.627	0.068	0.0001***
Condition: Preferred ear	0.170	0.075	0.0236*
Attended ear: Right	0.077	0.065	0.2364 (ns)
Semantic relatedness (unrelated)	-0.117	0.058	0.0432*
Attended language (Japanese)	1.526	0.054	0.0001***
Unattended language (Japanese)	-0.074	0.057	0.1982 (ns)
WMC	0.075	0.032	0.0176*
L2 proficiency	0.048	0.013	0.0001***
Condition (Preferred ear)* Attended ear (Right)	-0.203	0.097	0.0367*
Semantic relatedness (unrelated)* Unattended language (Japanese)	0.147	0.082	0.0722 (.)
Attended language (Japanese)* L2 proficiency	-0.049	0.014	0.0001***
Random Effect	Variance		
Participants	0.003856		

^a Model assumes baseline is a pair of semantically related passages, with English as the attended language presented to the non-preferred ear and English as the unattended language to the other ear.

* $p < .05$, *** $p < .0001$

A significant main effect of ear preference (Condition) was found, $\beta = 0.170$, $SE = 0.075$, $p < .05$, suggesting that maintaining attention to one language and inhibiting semantic and linguistic interferences from another language is better executed in the preferred ear than in the non-preferred ear (Preferred ear: $Mean = 1.536$, $SE = .049$; Non-preferred ear: $Mean = 1.451$, $SE = .049$). As has been seen in

each experiment, overall comprehension of both L1 and L2 in both the preferred and non-preferred ears was found to be ascribable to the degrees of WMC ($\beta = 0.075$, $SE = 0.032$, $p < .05$) and L2 proficiency ($\beta = 0.048$, $SE = 0.013$, $p < .001$), with WMC contributing more to comprehension. A significant two-way interaction between attended language and L2 proficiency means that L2 proficiency selectively contributes to comprehension of L2, but not that of L1, $\beta = -0.049$, $SE = 0.014$, $p < .001$.

The effect of ear preference was not subject to the differences in L2 proficiency ($\beta = 0.013$, $SE = 0.012$, $p = .2894$), WMC ($\beta = -0.043$, $SE = 0.064$, $p = .5071$), AoA ($\beta = -0.030$, $SE = 0.024$, $p = .2120$), and LoL ($\beta = -0.027$, $SE = 0.023$, $p = .2505$). No interactions between Condition and the other individual differences factors were significant, suggesting that the better performance in the preferred ear is not due to the differences in cognitive and experiential factors (Exposure (listening in L1): $\beta = -0.019$, $SE = 0.014$, $p = .1807$; Exposure (reading in L1): $\beta = -0.083$, $SE = 0.035$, $p = .8137$; Exposure (writing in L1): $\beta = -0.037$, $SE = 0.042$, $p = .3761$; Exposure (speaking in L1): $\beta = -0.061$, $SE = 0.033$, $p = .0673$; Exposure (listening in L2): $\beta = 0.069$, $SE = 0.065$, $p = .2928$; Exposure (reading in L2): $\beta = -0.065$, $SE = 0.084$, $p = .4417$; Exposure (writing in L2): $\beta = -0.050$, $SE = 0.124$, $p = .6865$; Exposure (speaking in L2): $\beta = -0.066$, $SE = 0.121$, $p = .5890$).

A four-way interaction between Condition, semantic relatedness, attended language, and unattended language was not significant, $\beta = 0.626$, $SE = 0.460$, $p = .1769$.

Language lateralisation among bilinguals

The attended ear, whether it was left or right, was found to have no influence on overall comprehension, $\beta = 0.077$, $SE = 0.065$, $p = .2364$, confirming that what seems to contribute to listening comprehension is not dependent on whether the attended ear is left or right. Instead, it seems to be affected by whether a listener consciously regards it as her preferred ear based on the intuitive decision through

years' of experiences in auditory processing. A significant interaction, however, between Condition (whether the preferred or non-preferred ear was used) and attended ear was found, $\beta = -0.203$, $SE = 0.097$, $p < .05$, demonstrating that using the right ear as the preferred ear in fact hinders comprehension, resulting in better comprehension in the left ear as the preferred ear than that in the right ear as the preferred ear (Left: $Mean = 1.733$, $SE = .105$; Right: $Mean = 1.481$, $SE = .058$), and better comprehension in the right ear as the non-preferred ear than that in the left ear as the non-preferred ear (Right: $Mean = 1.543$, $SE = .079$; Left: $Mean = 1.408$, $SE = .055$). Between the preferred and non-preferred ears, comprehension in the left ear as the preferred ear was better than that in the left ear as the non-preferred ear (Preferred left: $Mean = 1.733$, $SE = .105$; Non-preferred left: $Mean = 1.408$, $SE = .055$), and comprehension in the right ear as the non-preferred ear was better than that in the right ear as the preferred ear (Non-preferred right: $Mean = 1.543$, $SE = .079$; Preferred right: $Mean = 1.481$, $SE = .058$) (see Table 4.6). This two-way interaction was not further qualified by any continuous variable.

The participants who chose their left ear as their preferred ear were compared with those who chose their right ear as their preferred ear in their cognitive capacities and language experiences. There were no significant two-way interactions between attended ear and their AoA (left: $Mean = 11.636$; right: $Mean = 11.154$, $\beta = 0.002$, $SE = 0.027$, $p = .9505$), LoL (left: $Mean = 9.781$; right: $Mean = 10.073$, $\beta = -0.004$, $SE = 0.021$, $p = .8432$), and Exposure (listening in L2) (left: $Mean = 1.182$; right: $Mean = 1.141$, $\beta = -0.025$, $SE = 0.079$, $p = .7549$). This indicates that the significant differences in comprehension between the left and right ear as the preferred ear are not due to the participants' language experiences (e.g., Abutalebi, 2008; Abutalebi et al., 2005). On the other hand, there was a non-significant trend that the participants who chose their left ear had higher L2 proficiency (left: $Mean = 20.818$; right: $Mean = 18.923$) and WMC (left: $Mean = 2.864$; right: $Mean = 2.641$, $\beta = 0.001$, $SE = 0.253$, $p = .9714$; $\beta = 0.122$, $SE = 0.085$, $p = .1506$, respectively).

Table 4.6. *Mean Comprehension Scores as a Function of Condition and Attended Ear*

	Attended Ear	
	Left	Right
Condition	Preferred ear	Non-preferred ear
	1.733	1.481
	1.408	1.543

It may well be, however, that late bilinguals are not necessarily left-lateralised (e.g., Klein et al., 1999) (meaning that the right-ear-to-left-hemisphere route is preferred), because the right hemisphere is more involved if they acquire reasonably high L2 proficiency (e.g., Dehaene et al., 1997; Hull & Vaid, 2005). In addition, what is presented to the right ear is more efficiently inhibited by the contralateral brain organisations (e.g., ACC, DLPFC, and BG) that underpin the functioning of WMC (e.g., D’Esposito et al., 2000; Engle et al., 1999; Ilkowska & Engle, 2010). Higher L2 proficiency and WMC, although not significant, were also observed among participants who chose their right ear as the non-preferred ear and performed better than those who chose their left ear as their non-preferred ear. These results would indicate some possibility that the higher L2 proficiency and WMC bilinguals possess, the more right-lateralised they become (i.e., they tend to prefer to use their left ear). No further discussion as for the interaction between ear preference and attended ear, and the interaction between attended ear and continuous variables follows as the latter two-way interaction was not significant.

The significant effect of ear preference would suggest that 78% (39 out of 50) of the participants who chose their right ear as the preferred ear in Experiment 1 are left-lateralised (the right-ear-to-left-hemisphere route is used) and 22% (11 out of 50) who chose their left ear as the preferred ear are right-lateralised (the left-ear-to-right-hemisphere route is used) for processing both of their two languages⁹. These ratios support previous studies in the DL task where a pair of words in each language were

⁹ As the effect of attended ear and interaction between attended ear and attended language were not significant, no statement can be made as for which of the two languages is lateralised in which hemisphere.

presented, which suggest that late bilinguals (who started learning L2 after the age of 6) with reasonably high L2 proficiency are left lateralised for both languages (e.g., D'Anselmo et al., 2013; Green, 2003; Hull & Vaid, 2007; Morton et al., 1998; Ullman, 2001). As a pair of passages in the BDL task were presented in one or two different languages, one in each ear, and they had the same or different semantic relationships, it is suggested that the current results provide some evidence of lateralisation for cognitive control and language control in speech comprehension among late bilinguals under the near real-life listening condition. Caution has to be taken as for bilinguals' lateralisation patterns because they seem to be subject to the nature of the input stimuli, e.g., words, sentences, texts and the direction of translation (García, 2013). A further investigation is needed with regard to better performance in the left preferred ear than in the right preferred ear, although the results support previous studies that found a general tendency to recall an auditory verbal stimulus presented to the right ear better than a comparable stimulus presented simultaneously to the left ear (e.g., Bryden, 1963, 1988; Hugdahl, 1995).

4.3 Summary and Conclusions

The cross-experimental analysis between Experiment 1 where the preferred ear was used and Experiment 2 where the non-preferred ear was used sought to explore whether bilinguals would show ear preference (i.e., lateralisation) for processing meaningful passages in one language and overcoming semantic and linguistic interferences from the other language. As a result, the favourable ear-to-hemisphere route (i.e., the preferred ear) (e.g., Lambert, 1993; Proverbio & Adorni, 2011), whether it is left or right, was found to enhance bilingual speech comprehension. L2 proficiency and WMC seem to better subserve this favourable route, although plausible, than the unfavourable route when attention needs to be actively maintained to one language and another semantically related or unrelated language has to be effectively inhibited.

Although it is not clear as to why it was observed, the favourable *left-ear-to-right-hemisphere* route was in fact found to be better at maintaining attention to one language and inhibiting another than the favourable *right-ear-to-left-hemisphere* route, although most of the current participants (78%) chose their right ear as their preferred ear. Higher L2 proficiency and WMC, although not significant, among the participants whose preferred ear was their left ear (22%) leaves some possibility of contributions from these cognitive factors to the alteration of language lateralisation for bilingual speech comprehension. Hence, this finding would suggest that not all late bilinguals show left lateralised organisation (i.e., right-eared) (e.g., D'Anselmo et al., 2013; Green, 2003; Klein et al., 1999), and that, even if the bilingual participants are reasonably proficient, they would not always show bilateral activation (e.g., Dehaene et al., 1997), although these need neuroscientific verifications.

Evidence from ear behaviours among professional simultaneous interpreters (e.g., Hamers et al., 2002; Lambert, 1993; Proverbio & Adorni, 2011) suggests that ear preference for processing the bilinguals' two languages depends on the amount of experience in processing and switching between the languages. The current participants were obviously not as experienced in these language activities as simultaneous interpreters, hence their language experiences were not found to influence their ear preference. It could be mentioned, however, that even on the way to a higher level of bilingualism as can be found among simultaneous interpreters, a better ear-to-hemisphere route seems to be established.

The present results, although not comparable with previous studies on language lateralisation since they did not simultaneously include another language in their task stimuli (e.g., Soveri et al., 2011), would demonstrate that late bilinguals develop their favourable ear-to-hemisphere route for processing one language and controlling another, shown as variations of lateralisation for language control.

Experiments 1 and 2 have confirmed that the semantic relatedness of the unattended passage interrupts comprehension of the attended passage more than the semantic unrelatedness, and that even late bilinguals develop an ear-to-hemisphere

route, whether left or right, that works better for processing passages in one of their languages and suppressing another than the other ear-to-hemisphere route. However, an important question remains unanswered, namely what happens when attention is shifted. This is important because, on one hand, it is unclear whether the ear preference was utilised as the participants attended to only one of their ears throughout the BDL task. On the other hand, it is because previous studies have not paid much attention to executive control in auditory attentional control in maintenance of attention to one language and inhibition of another, although they have shown that bilinguals have better executive control in shifting attention and curbing task-irrelevant stimuli from the other channel (e.g., Bialystok, 2001, 2009; Filippi et al., 2012; Hugdahl et al., 2009; Soveri et al., 2011). Hence, Experiment 3 seeks to investigate bilinguals' auditory attentional control in speech comprehension by integrating an ear-switching paradigm into the BDL task.

CHAPTER 5: AUDITORY ATTENTIONAL CONTROL IN BILINGUAL SPEECH COMPREHENSION - EXPERIMENT 3

5.1 Auditory attentional control during comprehension of meaningful passages

Experiments 1 and 2 have demonstrated that semantic and language information is more processed and also better inhibited through the favourable ear-to-hemisphere route, and that speech comprehension performance through this favourable route is subserved by L2 proficiency and WMC, and they may influence language lateralisation for bilingual speech comprehension.

In the DL studies, it has been shown that there is an advantage of the right ear for processing speech stimuli when attention is directed to the right ear (forced-right: FR), although they are often syllable pairs, relative to the left ear (e.g., Hugdahl, 1995, 2003; Morton et al., 1998; Soveri et al., 2011). This right-ear advantage (REA) has been attributed to the more direct neurological network from the right ear to the left hemisphere (e.g., Hugdahl, 2003; Westerhausen & Hugdahl, 2010) where much of language processing is localised (e.g., Dehaene et al., 1997; Klein et al., 1999; Vaid & Hull, 2002), than the network from the left ear to the primary auditory cortex in the left hemisphere (e.g., Hugdahl, 2003; Kimura, 1967). A left-ear advantage has been in fact found when attention is directed to the left ear (forced-left: FL) (e.g., Hugdahl, 1995, 2003; Hugdahl et al., 2009). The REA has been also found among bilinguals and their performance has been found to be better than monolinguals (e.g., Soveri et al., 2011). The bilinguals were better in both FR and FL conditions than monolinguals, showing the bilinguals' efficient auditory attentional control and inhibition of task-irrelevant information. Soveri et al. (2011) asserted that the bilinguals' better performance than the monolinguals would be warranted by their higher executive control through years' of experiences in processing and switching between their two languages.

Then, how do bilinguals process their two languages in their brain? Would they also show different ear advantages for comprehension of one language while inhibiting another? The REA has been found among bilinguals in a dichotic listening task where consonant-vowel syllables are presented (e.g., Hugdahl et al., 2009; Soveri et al., 2011). A recent study has shown some evidence for the hemispheric specialisation for bilingual languages in the DL paradigm (D'Anselmo et al., 2013). Stimuli were pairs of words in each of the bilingual participants' languages. The languages of the participants were more similar (German and English) or less similar (Italian and English). The authors sought to explore the language lateralisation as a function of the degrees of similarity. As a result, linguistic similarities were found to influence the bilingual lateralisation for processing both languages. The proximity of structurally similar languages may require additional effort to avoid interference, which leads to more separate neural structures (Albert & Obler, 1978). A stronger REA was found for L2 (English) than for L1 (German) between the similar languages, whereas there was no difference in degrees of REA for L1 (Italian) and L2 (English) between the dissimilar languages.

Nonetheless, as the DL stimuli of words were presented in each language, whether the REA they found would also entail effective language control from the other language is not clear. If bilinguals have better executive control in shifting attention and blocking task-irrelevant cues from the other channel (e.g., Bialystok, 2001, 2009; Filippi et al., 2012; Hugdahl et al., 2009; Soveri et al., 2011), they would also show efficient auditory attentional control in inhibiting another language when their attention is paid to one language, that is to be shown as an REA.

5.1.1 Attention shifting and WMC in the DL task

In DL studies where the role of WMC was considered, high-span monolingual participants were found to be better able to selectively attend to the target channel and inhibit interfering information from the other channel compared to low-spans (e.g., Colflesh & Conway, 2007; Conway et al., 2001). Cognitive control advantages

among bilinguals have been found in task switching (e.g., Prior & MacWhinney, 2010) and suppressing irrelevant information (e.g., Bialystok, 2009) in tasks calling for inhibition of task-irrelevant cues (Bialystok, 2001). Studies comparing monolinguals with bilinguals have also shown bilinguals' advantage in attentional control in the DL task, in that bilingual participants are better able to shift their attention (from left to right or from right to left ear) and suppress task-irrelevant auditory information than monolinguals (Soveri et al., 2011)

Experiment 3 consistently considered the role of WMC in auditory attentional control required in the BDL task, and the role of L2 proficiency since the auditory stimuli in the BDL task were not presented in only one language, but the participants' two languages. Experiment 3 sought to confirm whether performance in the BDL would be related to WMC, L2 proficiency, or both.

5.2 Attentional control and language control in bilingual speech comprehension

Experiment 3 aims to further investigate the bilingual's ear advantage for processing their two languages in the BDL task, where attention has to be paid to one language while inhibiting another simultaneously activated language. The BDL task would produce a more cognitively demanding situation than when only syllables or words are presented, which would aid investigations of bilingual speech comprehension at the passage level. As the participants in Experiments 1 and 2 consistently attended to only one of the channels, either their preferred ear or non-preferred ear, it could be that they were able to maintain their attention to that channel because they did not control attention to which channel they had to attend. Hence, a change had to be made to experimental manipulations for Experiment 3.

As it has been confirmed in Experiments 1 and 2 that semantic relatedness influences bilingual speech comprehension, and that ear preference does in fact enhance listening performance in the BDL task, these experimental manipulations were not considered in Experiment 3. Instead, an ear switching paradigm was

introduced to delve into bilingual auditory attentional control and investigate whether there would be an REA at the meaningful passage level among bilingual listeners. To reiterate, an REA expected to be found in this experiment has to do with not only comprehension, but also language control. The main conflict the participants had to overcome came from the shifting of attention (i.e., ears), and secondly from the unattended language in the unattended channel. Attention had to be maintained to one of their languages as in Experiments 1 and 2.

5.2.1 Hypotheses

Three hypotheses are presented below as for auditory attentional control in bilingual speech comprehension of passages in one language while inhibiting another and the role of executive control in effective attention shifting required to comprehend both languages in each ear.

- I. There will be a right-ear advantage for comprehending passages in both languages and controlling language interference.

Previous DL studies on bilinguals show the bilinguals' advantage in focusing their attention to the relevant stimuli and suppressing irrelevant stimuli and the bilinguals' significant REA (e.g., Hugdahl et al., 2009; Soveri et al., 2011). As their DL stimuli were consistently consonant-vowel syllable pairs, there is little credibility regarding the bilinguals' executive control in focusing their attention to a relevant language and inhibiting an irrelevant language. Even when the bilinguals' language comprehension (sentences) was considered (Filippi et al., 2012), the bilinguals' attentional control and inhibition of task-irrelevant language was not considered (there is no mention of ear to which the target and interference sentences were presented). Hence, Experiment 3 was motivated to extend their studies and explore whether an REA would be observed for comprehension of passages in the bilinguals' two languages and, moreover, for inhibition of an unattended passage in the task-irrelevant

language. The question is: With which ear would the participant be able to maintain attention more efficiently to one language and inhibit another?

II. Within channel, one unattended language is harder to inhibit than the other unattended language.

Within ear, would within-language (i.e., unattended English on attended English, and unattended Japanese on attended Japanese) competition be stronger than between-language (i.e., unattended Japanese on attended English, and unattended English on attended Japanese) competition or vice versa? The first two hypotheses inquire whether the interference from the unattended language would be different *between ears*, by investigating whether performance in one ear would be better than that in the other ear (e.g., RTEE vs. LTEE). In Experiment 1, it was found that comprehension was better when the unattended language was Japanese than when it was English *within* ear (i.e., the preferred ear), and that in fact the left eared participants performed better than the right-eared participants. While investigating bilingual auditory attentional control, Experiment 3 seeks to examine how much of interference from one language is placed on another language *within ear*. When attention is forced to one of the channels, it could reveal how efficiently bilinguals can maintain their attention to one language and inhibit another in "each" ear.

Although there are few data which can be easily compared with those of the current experiment, as the forced-left condition specifically requires the ability to resolve a cognitive conflict between the stronger tendency to report the right-ear stimulus and the instruction to report the weaker left-ear stimulus (e.g., Bryden, 1963; Hugdahl, 2003; Kimura, 1967; Morton et al., 1998; Westerhausen & Hugdahl, 2010, p. 480), it would be more difficult for the participants to focus their attention to English presented in the left ear and ignore English presented in the right ear (LTEE), than when attending to English in the left ear and inhibiting Japanese in the right ear (LTEJ), since it was shown in Experiment 1 that unattended Japanese casts less interference than unattended English on comprehension of the attended language.

The similar degree of interference from the unattended language would be also seen when Japanese is the attended language (i.e., LTJJ > LTJE). Within the right ear, it would be effortless to comprehend passages, which would also mean that interference from the left ear is not detectable (i.e., RTEE \approx RTEJ, and RTJE \approx RTJJ).

III. High WMC and L2 proficiency are crucial for the efficient attentional control and language control.

In DL studies where the role of WMC has been found to be crucial, researchers have maintained that switching between ears and maintaining attention to one of them requires effective inhibition of interference from the stimuli presented to the other ear and steering attention to the attended ear (e.g., Colflesh & Conway, 2007; Conway et al., 2001; Hugdahl et al., 2009), and especially, successful attention shifting to the left ear requires stronger cognitive effort (Hugdahl, 2003, p. 447), all of which are subserved by WMC (e.g., Conway & Engle, 1994; Engle & Kane, 2004; Osaka & Osaka, 2007; Sylvester et al., 2003). Executive control is also vital for language control in bilingual auditory comprehension (e.g., Abutalebi et al., 2007). L2 proficiency has been also found to be associated with better control of interference from both of the bilingual's languages (Filippi et al., 2012).

Hence, it was predicted that bilingual listeners would exhibit their executive control capacity in successful attention shifting from one channel to another, and effective language control from another language in each channel.

5.3 Methods

5.3.1 *Participants*

97 Japanese-English bilinguals (52 females) took part in the experiment in return for a reward. All of them were right-handed, with normal or corrected-to-normal vision

Table 5.1. *Participants' Gender, Cognitive, and Experiential Characteristics (Experiment 3)*

Gender	English Proficiency	WMC^b	Age	AoA^c	LoL^d
M: 45, F: 52	18.22 (3.40) B2-C1 ^a	3.08 (.828)	19.51 (1.25)	11.42 (2.72)	8.28 (2.56)
Ear Preference^e	Universities^f				
R: 51, L: 19, B: 27	Tokyo Gakugei University (Tokyo), Dokkyo University (Saitama), and Hokkaido University of Education, Hakodate (Hokkaido)				

Note. M: Males, F: Females. R: Right, L: Left. Standard deviations are presented in parentheses.

^a Scales indicated in the Common European Framework of References scales (Council of Europe, 2001). Max = 30

^b Max = 5.0

^c Age of L2 acquisition.

^d Length of L2 learning.

^e R: Right, L: Left, B: Both.

^f Universities where the participants were collected.

and reported no hearing disabilities. The details of the participants are summarised in Table 5.1.

5.3.2 *Materials*

The same set of materials (earedness questionnaire, proficiency test, and RST), except the BDL task where the auditory stimuli were all semantically related and shifting of attended ear was required, was used.

BDL Task

The thirty-two pairs of semantically related passages (i.e., basic eight semantically related pairs of passages counterbalanced in a Latin square, producing thirty-two pairs) in the four language conditions (i.e., English-English, English-Japanese, Japanese-English, and Japanese-Japanese) used in both Experiments 1 and 2 formed a half of the BDL stimuli presented to the left ear in Experiment 3. The other half of

thirty-two pairs of semantically related passages presented to the right ear were made in the same procedure as described in the Methods section of Experiment 1. The average readability ratios of the English texts were 41.31 (Flesch Reading Ease) and 12.63 (Flesch-Kincaid Grade Level). The English texts were found to be relatively difficult, but suitable for college students.

A semantic relatedness score of the other half of pairs of English texts was 0.73 on average (LSA @ CU Boulder, Landauer et al., 1998), which was confirmed to be not significantly different from that of another half (semantic relatedness score: 0.77), $t(14) = 1.740$, $p = .104$). The English texts were then translated into Japanese and were analysed for their readability with Obi-2: Readability Analyser of Japanese Texts (Sato et al., 2008). They were either relatively difficult to read or readable for those at a ninth-grade or higher reading level (*Mean*: 6.5 (B9 Scale, 9: most difficult)). Speech rates of the English passages and translated Japanese passages were 172.38 words per minute and 431.5 characters per minute, respectively.

A total of sixteen pairs of passages, consisting of two sets of pairs of passages in the eight language conditions, were produced (see Appendix C.1). Eight pairs of passages were presented to left and the other eight pairs to the right ear (see Table 5.2). Two trials in each of eight conditions was given to each participant. Comprehension was assessed in the sentence-complete task. The ear to attend to was cued three seconds before each auditory stimulus by an arrow (left: ←, right: →) on the Keynote slide.

The BDL task in Experiment 3 included two attention manipulation conditions: forced-right (FR), and forced-left (FL). A non-forced (NF) condition, where participants are required to recall a stimulus through the ear they heard better, which is usually incorporated in a DL study (e.g., Hugdahl et al., 2009; Soveri et al., 2011), was not added to the current BDL task. As the auditory stimuli in the BDL task were heard not in one language, but in two languages, and comprehension of each language was the focal point of assessment, it was thought senseless to include the NF condition in this experiment. Thus, although a laterality index, i.e., [(Right ear -

Table 5.2. *Example Presentation Orders of Sixteen Pairs of Passages to Subjects 1 and 2*

Subject 1	Attended Channel	Pairs of texts	Subject 2	Attended Channel	Pairs of texts
1	L	E-J	1	R	J-E
2	R	J-J	2	L	J-J
3	L	E-E	3	R	J-E
4	R	J-J	4	L	E-E
5	L	J-E	5	R	E-J
6	R	E-J	6	L	J-E
7	L	J-J	7	R	E-E
8	R	E-E	8	L	E-J
9	L	E-J	9	R	J-J
10	R	J-E	10	L	E-E
11	L	J-J	11	R	J-J
12	R	J-E	12	L	J-E
13	L	E-E	13	R	E-J
14	R	E-J	14	L	J-J
15	L	J-E	15	R	E-E
16	R	E-E	16	L	E-J

Note. E for English, J for Japanese, L for left, and R for right. The order of ear switching was alternated such as L, R, L, R for Subject 1 and R, L, R, L for Subject 2, and the order of attended language was presented at random such as E, E, J, J, or E, J, J, E. As language switching paradigm was not considered in Experiment 3, presenting the same language consecutively would not influence the result, however, what may influence the result is that the same condition should not be consecutively given. Each participant was given counterbalanced texts which were presented in the alternating order of ears, i.e., L, R, L, R or R, L, R, L and in the four conditions, i.e., English-English, English-Japanese, Japanese-Japanese, and Japanese-English. Texts are randomised *within* ear, e.g., texts presented to the left ear were E-J, E-E, J-E, J-J, E-J, J-J, E-E, and J-E, and those presented to the right ear were J-J, J-J, E-J, E-E, J-E, J-E, E-J, and E-E.

Left ear)/(Right ear + Left ear)]*100 (Hugdahl & Andersson, 1986), is conventionally shown based on data in the NF condition, a relative ear advantage is

shown by the ratio of the FR performance compared to the FL performance, i.e., $[(FR - FL)/(FR + FL)] * 100$, in the current experiment.

5.3.3 Design

Experiment 3 employed a BDL task with a few adjustments to achieve the purpose of investigating bilingual auditory attentional control. Experimental conditions in the BDL task included attended channel (left ear or right ear), attended language (English or Japanese), and unattended language (English or Japanese). As explained below, the participants were instructed to switch their ears (e.g., from left to right or from right to left) between trials in an alternating order while receiving one language in one ear and another (same or different) in the other ear.

Experiment 3 had a three-way repeated measures design. The independent variables were attended channel, attended language, and unattended language. Each independent variable had two levels: left ear or right ear (attended channel); English or Japanese (attended language); and English and Japanese (unattended language). The dependent variable was the number of questions in a sentence-completion task for each pair of passages the participant answered correctly. Misspellings were counted as errors.

Effects of individual differences factors such as L2 proficiency, WMC, AoA, LoL, and Exposures to each language, were consistently considered to investigate whether they would contribute to the efficiency in ear switching in the BDL task for the same reasons as in 3.2.2.3. They were analysed for the effects on the dependent variable.

5.3.4 Procedure

The current participants were given the tasks (the earedness questionnaire, proficiency test, RST (ESL), and BDL task) in the identical way as in Experiments 1 and 2, except that they were instructed to switch their ears in an alternating order in

the BDL task. The attended language was randomly presented as in Experiments 1 and 2. The attended ear was cued three seconds before the start of each auditory stimulus by an arrow (left: \leftarrow , right: \rightarrow) on each side of the Keynote slide. Presentation orders of the FR and FL conditions were counterbalanced so that every other participant did FR before FL and vice versa. Examples of BDL stimuli presentation orders are shown in Table 5.1.

5.3.5 Analysis

5.3.5.1 Scoring

Scoring in the proficiency test and RST (ESL) was administered in the same way as in Experiments 1 and 2. Sentence-completion tasks with scores ranging from 0 to 5 for each auditory stimulus were also given in the BDL task in Experiment 3. As what the participants had to do was answer comprehension questions for the passage they just heard in the attended ear, although the pair of passages were semantically related (i.e., semantically similar words were used), answers drawn from the unattended passage were treated as errors.

5.3.5.2 Data analysis

The data were analysed in the GLMM as in Experiments 1 and 2. The same model was applied to comprehension of each of eight states (i.e., RTEE, RTEJ, RTJE, RTJJ, LTEE, LTEJ, LTJE, and LTJJ). Participants were a random effect (random intercepts only), and attended channel (treatment coded: left vs. right; left = baseline), attended language (treatment coded: English vs. Japanese; English = baseline), and unattended language (treatment coded: English vs. Japanese; English = baseline) were fixed effects.

The individual differences factors were also included as fixed effects to explain variance due to differences in L2 proficiency (continuous), WMC (continuous), AoA (continuous), LoL (continuous), Exposures to L1 and L2 in listening, reading,

Table 5.3. *Mean Comprehension Scores of English and Japanese in the Left Ear and Right Ear in Each Condition (Experiment 3)*

		Attended Language			
		English		Japanese	
Attended Channel		Unattended Language		Unattended Language	
		English	Japanese	English	Japanese
	Left	.53 (.494)	.55 (.614)	2.14 (1.15)	1.93 (.693)
	Right	.70 (.619)	.72 (.625)	3.07 (1.11)	2.66 (1.22)

Note. $N = 97$. Standard deviations are presented in parentheses.

writing, and speaking (all continuous) and earedness (treatment coded: left vs. right; left = baseline). Most fitted models after entering these fixed effects into the model and removing non-significant fixed effects and interactions are presented as the final model.

5.3.6 Results

Means of comprehension in each language in each condition are shown in Table 5.3 with standard deviations in parentheses. Results of the GLMM of comprehension of English and Japanese are summarised in Tables 5.4 and 5.5 (see Appendix C.2), respectively.

Effects of attended channel, attended language and unattended language

Hypothesis I was tested by finding a significant main effect of attended channel. There was a distinctly significant main effect of attended channel ($\beta = 0.325$, $SE = 0.042$, $p < .001$), with better comprehension of passages heard in the right ear than in the left ear ($Mean = 1.786$, $SE = .064$; $Mean = 1.290$, $SE = .057$, respectively) (see Figure 5.1). As expected, a highly significant main effect of attended language, $\beta = 1.367$, $SE = 0.051$, $p < .001$, with better comprehension when the attended language is Japanese than when it is English was found ($Mean = 2.451$, $SE = .085$;

Table 5.4. *Coefficients (betas), Standard Errors (SEs), and p Values for Generalised Linear Mixed Models of Listening Comprehension in the BDL Task (Experiment 3)*

Fixed Effects	Comprehension		
	<i>beta</i>	<i>SE</i>	<i>p</i>
(Intercept) ^a	-0.650	0.063	0.0001***
Attended channel (right)	0.325	0.042	0.0001***
Attended language (Japanese)	1.367	0.051	0.0001***
Unattended language (Japanese)	-0.093	0.041	0.0234*
WMC	0.075	0.045	0.0966(.)
L2 proficiency	0.026	0.011	0.0198*
Random Effect	Variance		
Participants	0.093474		

^a Model assumes baseline is a pair of semantically related passages, with left ear as the attended channel, with English as the attended language and English as the unattended language.
(.) $p < .10$, * $p < .05$, *** $p < .0001$

Mean = .625, *SE* = .044, respectively). There was another significant main effect of unattended language, *beta* = -0.093, *SE* = 0.041, $p < .05$, with better comprehension when the unattended language is English than when it is Japanese (*Mean* = 1.610, *SE* = .063; *Mean* = 1.466, *SE* = .057, respectively). No two- and three-way interactions between attended channel, attended language, and unattended language reached significance (attended channel*attended language, *beta* = 0.087, *SE* = 0.146, $p = .5494$, attended channel*unattended language, *beta* = -0.002, *SE* = 0.184, $p = .9927$, attended language*unattended language, *beta* = -0.142, *SE* = 0.156, $p = .3622$, and attended channel*attended language*unattended language, *beta* = -0.037, *SE* = 0.206, $p = .8574$). Although 52.577% (51 out of 97) of the current participants chose their right ear, 19.587% (19 out of 97) their left ear, and 27.835% (27 out of 97) both

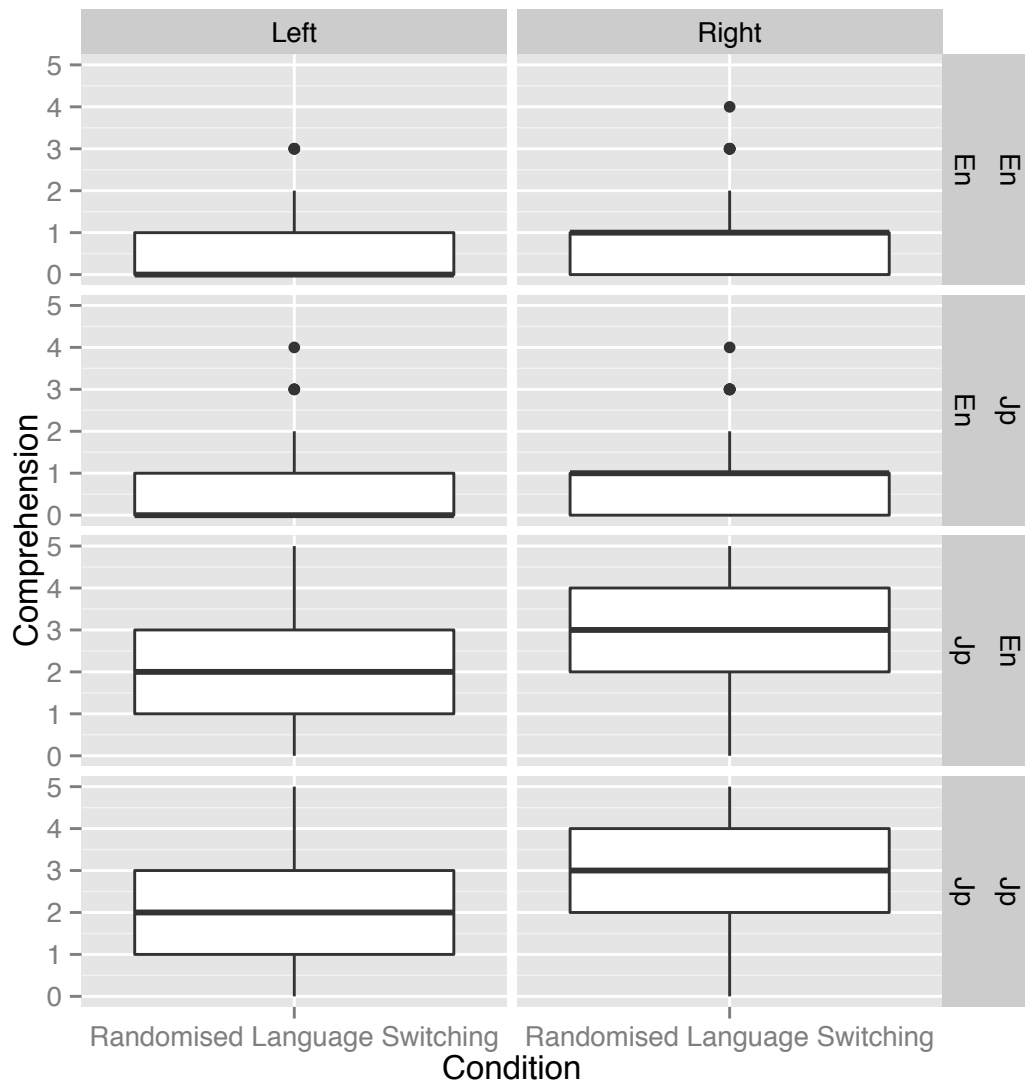


Figure 5.1. Boxplots showing the interquartile ranges of comprehension scores for conditions of the passages presented to the right ear (RTEE, RTEJ, RTJE, and RTJJ) and the passages presented to the left ear (LTEE, LTEJ, LTJE, and LTJJ) (Experiment 3). En: English; Jp: Japanese. The first label in the row name refers to the attended languages and the second label in the row name refers to the unattended languages. Condition denotes that the attended languages were randomly presented. Medians are presented with the thick horizontal bars. Dots in the figure represent data points that are outside of the 95% confidence interval, which is shown by the vertical lines extending beyond the first and third quartile hinges.

ears as their preferred ear (i.e., earedness), the effect of earedness, whether left, right, or both, was not significant (left vs. both: $\beta = 0.112$, $SE = 0.111$, $p = .3097$; left vs. right: $\beta = 0.020$, $SE = 0.101$, $p = .8413$; right vs. both: $\beta = 0.092$, $SE =$

0.086, $p = .2833$). Hence, the results of comprehension in the BDL task in Experiment 3 were not due to the participants' earedness.

Hypotheses II was tested by comparing comprehension between the four conditions in each attended language and inspecting whether an influence from the unattended channel would be different both within (i.e., RTEE vs RTEJ, RTJE vs RTJJ, LTEE vs LTEJ, and LTJE vs LTJJ) and between channels (i.e., RTEE vs LTEE, RTEJ vs LTEJ, RTJE vs LTJE, RTJJ vs LTJJ, and RTJE vs. LTJJ) (see Table 5.5 in Appendix C.2), as a three-way interaction between attended ear, attended language, and unattended language was not significant, $\beta = -0.037$, $SE = 0.206$, $p = .8575$. As the significant main effect of attended ear indicates, between-ear comparisons showed significantly better comprehension in the right ear between all comparisons (RTEE (*Mean*: .70) > LTEE (*Mean*: .53), $\beta = 0.271$, $SE = 0.131$, $p < .05$; RTEJ (*Mean*: .72) > LTEJ (*Mean*: .55), $\beta = 0.269$, $SE = 0.129$, $p < .05$; RTJE (*Mean*: 3.07) > LTJE (*Mean*: 2.14), $\beta = 0.358$, $SE = 0.064$, $p < .001$; RTJJ (*Mean*: 2.66) > LTJJ (*Mean*: 1.93), $\beta = 0.462$, $SE = 0.066$, $p < .001$), and RTJE (*Mean*: 3.07) > LTJJ (*Mean*: 1.93), $\beta = 0.319$, $SE = 0.068$, $p < .001$), hence indicating a significant REA in inhibiting both within and between-language competition relative to the left ear.

Among within-ear comparisons, a significant difference was found between RTJE and RTJJ with better comprehension in RTJE (RTJE (*Mean*: 3.07) > RTJJ (*Mean*: 2.66), $\beta = 0.142$, $SE = 0.060$, $p < .05$), suggesting that within the right ear the unattended Japanese presented to the left ear is more interfering than the unattended English presented to the left ear. The between-language competition seems to be stronger when the attended language is Japanese than the within-language competition in the right ear. The other within-ear comparisons did not reach significance (RTEE (*Mean*: .70) \approx RTEJ (*Mean*: .72), $\beta = 0.036$, $SE = 0.121$, $p = .7636$; LTEE (*Mean*: .53) \approx LTEJ (*Mean*: .55), $\beta = 0.038$, $SE = 0.138$, $p = .7830$; and LTJE (*Mean*: 2.14) \approx LTJJ (*Mean*: 1.93), $\beta = 0.104$, $SE = 0.071$, $p = .1460$). These results indicate that comprehension of Japanese in the right ear is more interfered with by the same Japanese language, but not by the different English

language, and interference from both English and Japanese on comprehension of English in the right ear seems to be comparable. On the other hand, comprehension of both languages in the left ear seems to receive no apparent interference from either languages from the right ear.

The results of performance in the left ear would show that when attention is paid to the left ear, it is more efficient to inhibit simultaneously presented information, regardless of language, from the right ear than when attention is paid to the right ear. However, L2 proficiency and WMC did not particularly contribute to the performance in the left ear ($\beta = 0.016$, $SE = 0.012$, $p = .1972$, and $\beta = 0.026$, $SE = 0.050$, $p = .6038$, respectively). Hence, the current results would suggest that stimuli presented to the right ear are less processed when attention is paid to the less automatised channel, thereby the unattended language in the right ear does not interrupt processing of the attended language in the left ear.

Individual differences factors

Hypothesis III was tested in a GLMM with Poisson error distribution by finding significant main effects of continuous variables on the dependent variable. Results of the GLMM with Poisson error distribution where comprehension of each state (i.e., RTEE, RTEJ, RTJE, RTJJ, LTEE, LTEJ, LTJE, and LTJJ) is the dependent variable, WMC, and L2 proficiency are fixed factors, and participants is the random effect, are shown in Table 5.4. Presumably the most relevant experiential factor, the amount of listening in L2 was not found to significantly predict the dependent variable ($\beta = 0.050$, $SE = 0.046$, $p = .2730$, $Mean = .99$ hours, $SD = 1.23$, 4.66% of the total amount of time in L1 and L2), hence, it was not included in the final model. Effects of the other individual differences factors were found to be non-significant, hence, they were not also included in the final model.

Overall comprehension of both L1 and L2 was found to be marginally ascribable to the degrees of WMC ($\beta = 0.075$, $SE = 0.045$, $p = .0966$), but significantly to L2 proficiency ($\beta = 0.026$, $SE = 0.011$, $p < .05$).

5.3.7 Discussion

5.3.7.1 Attentional control in bilingual speech comprehension

The BDL task with passages as auditory stimuli and a top-down instruction to switch between ears has contributed to the current findings in Experiment 3 that bilingual listeners perform better in their right ear than in their left ear while switching ears, while maintaining their attention to one language, and suppressing another in each ear, whether the attended language is L1 or L2 and whether the unattended language is L1 or L2. These results substantiate Hypothesis I that bilinguals demonstrate a right-ear advantage for comprehending passages in both languages and controlling language interference. By adding instructions to explicitly focus attention on either the right or left ear stimulus, top-down attentional modulation of the lateralised perceptual REA effect is obtained (Hugdahl et al., 2009). The REA was clearly seen in the current BDL task.

Notably, the current findings in the BDL task denote that bilingual listeners are able to effectively shift their attention between ears, comprehend the relevant stimulus, and suppress the irrelevant stimulus, while overcoming both within- and between-language competition, even when the stimuli are one-minute long passages. These findings are consistent with previous DL studies with syllables, words, and sentences (e.g., Beaman, 2004; Filippi et al., 2012; Hugdahl et al., 2004; Sörqvist et al., 2008; Soveri et al., 2011), and would further their findings to the comprehension of passages while suppressing another language simultaneously presented to the other channel, which resembles the actual processing occurring in the bilingual mind.

The REA is scored as a lateralisation index, defined by the number of correctly repeated items presented to the right ear minus the number of correctly repeated items to the left ear, divided by the total number of correct answers for both ears (Hugdahl, 2003). A laterality index (LI) based on the formula $[(FR - FL)/(FR + FL)] * 100$, as shown earlier, was calculated. An LI of 16.12 was obtained $[(1.786 - 1.290)/(1.786 + 1.290)] * 100$, that is similar to the laterality index such as 17.61 found among the participants in the Bergen Dichotic Listening test (e.g., Hugdahl,

1995). A positive LI indicates an REA, and a negative index an LEA. Since the LI of 17.61 was found among right-handed participants ($N = 825$) (e.g., Hugdahl, 1995), the LI of 16.12 found among the current participants ($N = 97$) who were all right-handed could be showing an equivalent result. What seems to be remarkable is that an LI indicating an REA was indeed found in the BDL task where the participants *comprehended* pairs of one-minute length meaningful passages in their two languages that clearly put more cognitive demands than the pairs of CV syllables presented in the Bergen Dichotic Listening test (e.g., Hugdahl, 1995).

Caution needs to be taken, however, regarding the relative advantage in the right ear in the BDL task, since attention was directed by the top-down instruction, unlike in the NF condition where no such top-down instruction is given. In addition, as the current participants were reminded that they were not supposed to attend to the opposite ear and their focus was placed on comprehension of the language in the attended channel, an REA observed when attention is free from forced top-down instruction (i.e., NF condition) is not as same as the REA reported in the BDL task.

Nevertheless, it would be uncontrollable to instruct participants to recall information in one of their languages in the NF condition in the BDL task since it seems likely that information in the dominant language would be only recalled even when they hear two languages, one in each ear, and a forced-attention condition is produced the moment they are told what language to recall. Therefore, an REA in this dissertation is regarded as a relative advantage of the right ear in comprehending one language while inhibiting another language compared to the left ear.

Comprehension of Japanese, the participants' dominant language, was consistently and significantly better than that of English, their non-dominant language, which is invariably unarguable and plausible. Contrary to the finding in Experiment 1, the negative effect of Japanese as the unattended language on comprehension was found in Experiment 3, which needs some discussion.

Results from previous studies (e.g., Blumenfeld & Marian, 2007; de Groot, 2011; Marian & Spivey, 2003a, 2003b; Spivey & Marian, 1999; Weber & Cutler, 2004), however, cannot be compared with the current results as explained in 3.2.5.1, that

interference from the same auditory modality is much stronger than that from a different visual modality on the target auditory stimulus (e.g., Latorella, 1998; Rees et al., 2001; Stanton et al., 1992). A simple comparison between Experiments 1 and 3 cannot be made to draw a conclusion as for the different effects of Japanese as the unattended language, either, as their experimental manipulations are different in that the passages entailed same or different semantic relationships in Experiment 1, whereas the passages were all semantically related in Experiment 3, and attention was fixed to one of the ears in Experiment 1, whereas attention was switched between trials in Experiment 3. Nonetheless, Hypothesis II that within channel one unattended language is harder to inhibit than the other unattended language is moderately supported by the finding that within the right ear it is significantly harder to suppress Japanese than English when the attended language is also Japanese. A clearer effect of Japanese as the unattended language is expected to be found in the following experiment (Experiment 6), and further discussion is given once comparisons are made between Experiments 3 and 6.

5.3.7.2 *Cognitive underpinnings for bilingual speech comprehension*

Factors that may help sustain bilingual speech comprehension that involves attentional control and language control in maintenance of attention to one language and inhibition of another were examined by considering effects of continuous variables such as WMC, L2 proficiency, AoA, LoL, Exposures (reading, listening, writing, and speaking) in L1 and L2 in the same GLMM with Poisson error distribution. Results showed that effectively switching and maintaining attention to the target channel and language and resolving within- and between-language competition from the unattended channel requires high L2 proficiency (Filippi et al., 2012), but not WMC, which partially supports Hypothesis III.

The marginally significant effect of WMC on speech comprehension in the BDL task was unpredicted as recent DL studies support the significant role of WMC in effective switching between channels, maintenance of attention to the relevant

stimuli, and suppression of the irrelevant stimuli in the DL task (e.g., Colflesh & Conway, 2007; Conway et al., 2001; Hugdahl et al., 2009; Soveri et al., 2011). WMC is suggested to be most required when task-relevant information has to be actively maintained to guide response selection, especially if task-irrelevant information is available at the same time (Engle & Kane, 2004). Indeed, the BDL condition involves both task-relevant and task-irrelevant information, where WMC should demonstrate its role.

The difference between their studies and the current experiment is that they collected both high-span and low-span monolinguals, or both monolinguals and bilinguals, and compared their performance based on their WMC measures, whereas in the current experiment only bilinguals were recruited and regression analyses were conducted to determine the relationship between the participants' performance in the BDL task and their WMC. The more significant difference lies in the experimental manipulations. Syllable and word pairs were used in their studies, whereas passage pairs in two languages were used in the current BDL task. As processing a larger linguistic unit is more cognitively demanding (e.g., Daneman & Carpenter, 1980; King & Just, 1991) and doing a less-automatised task (i.e., listening in L2 and doing a DL task) puts high demands on WM (Baddeley, 2007; Tyler, 2001), the significant role of WMC, that was found in Experiment 1, was predicted to be also observed in Experiment 3.

The major difference in the BDL stimuli between Experiment 1 and Experiment 3 was that the passages were semantically related and unrelated in Experiment 1 and they were all semantically related in Experiment 3. Hence, it is speculated that when there is a rich source of semantic competition (both semantically related and unrelated passages in Experiment 1), WMC seems to be more demanded (e.g., Thompson-Schill, 2003; Thompson-Schill et al., 1997) than when there is less competition (only semantically related passages in Experiment 3). It could be that the participants realised that the pairs of passages were about the same topic, hence, they focused on differences in language (i.e., whether they are in the same or different

languages) between the attended and unattended languages, which resulted in less requirement for WMC to resolve semantic competition.

Brain regions for resolving semantic competition have been found to be the left inferior frontal gyrus and left middle frontal gyrus (e.g., Badre et al., 2005), which are also crucial areas (e.g., Jäncke & Shah, 2002) for attentional focusing, ignoring irrelevant information, and resolving a response conflict found in DL studies (e.g., Hugdahl et al., 2009; Thomsen et al., 2004). Therefore, WMC was significantly required in Experiment 1, but not in Experiment 3.

It is concluded that in the present BDL task L2 proficiency plays its significant role in attentional control between semantically related passages in both of the participants' languages and resolving within- and between-language competition in each ear.

5.4 Summary and Conclusions

Experiment 3 was conducted to investigate auditory attentional control in bilingual speech comprehension of meaningful passages, within- and between-language competition in each ear, and the roles of executive control and experiential factors in effective attention shifting between ears, maintenance of attention to one language, and suppression of another language within ear. The present results have demonstrated that bilinguals show the REA (e.g., Hugdahl et al., 2009) even when the auditory stimuli are passages as long as one minute and heard in their two languages as indicated by the positive laterality index (e.g., Hugdahl, 1995). This suggests that bilinguals' two languages are better processed through their right ear when the top-down instructions (i.e., forced-right and forced-left) (e.g., Hugdahl, 1995) are given and even when there is another auditory stimulus in one of their languages at the same time.

Japanese as the unattended language was found to be more interfering than English, whether the attended language is English or Japanese. Comprehension of the dominant language is undeniably better than that of English regardless of the

attended ear and language in the unattended ear. The within-ear analyses have shown that Japanese is more disruptive than English when the attended language is Japanese in the right ear, and the unattended language, whether it is English or Japanese, seems to be less processed, so less disruptive to comprehension in the left ear.

The BDL task without semantic relationships between passages presented to each ear and with a top-down instruction to switch between ears has exhibited a less involvement of WMC and a more involvement of L2 proficiency in efficient attention shifting and suppression of the task-irrelevant stimulus. In other words, the BDL task with different experimental manipulations could explore different aspects of bilingual speech comprehension and how cognitive and experiential characteristics are related to the processing.

The current data would advance the previous studies on auditory attentional control (e.g., Hugdahl et al., 2009) and bilingual executive control (e.g., Filippi et al., 2012; Soveri et al., 2011) in that the current findings demonstrate that the use of passage stimuli in the DL paradigm is in fact effective in probing attention shifting (e.g., Colflesh & Conway, 2007) and that presenting the DL stimuli in the two languages can shed light on differences between ears in processing one language and inhibiting another (e.g., Thomsen et al., 2004).

The next chapter presents replications of Experiments 1, 2, and 3, while considering the effect of note-taking (Experiments 4, 5, and 6), which is what listeners commonly do when they are engaged in real-life speech comprehension of passages, to explore the executive control in bilingual speech comprehension in everyday situations. Cross-experimental analyses (between Experiments 1 and 4, between Experiments 2 and 5, and between Experiments 3 and 6) are conducted to investigate the effect of note-taking and whether note-taking would have any effect on the maintenance of attention to one language and inhibition of another. Experiment 4 is compared with Experiment 5 to examine the effect of ear preference as it was investigated between Experiments 1 and 2.

CHAPTER 6: INVESTIGATIONS OF THE EFFECTS OF NOTE-TAKING - EXPERIMENTS 4, 5, and 6

6.1 Note-taking in psychology experiments

Experiments in cognitive psychology, psycholinguistics, and bilingualism exploring speech comprehension commonly employ online measures such as reaction times in a grammaticality judgement task (e.g., Bialystok, 2009) or a visual/spoken word recognition task (e.g., Dijkstra & van Hueven, 1998; Marian & Spivey, 2003a). However, in the real-life situations, listeners perceive not only isolated words out of context, but sentences and passages (Ingvalson et al., 2014), which are often accompanied by note-taking (Piolat et al., 2005).

There have been various findings with regard to the effectiveness of note-taking on comprehension of passages. On one hand, negative aspects of note-taking have been shown when note-takers are pressed to take notes (Hale & Courtney, 1994), that is when they cannot decide when to take notes and when not to take notes (Lin, 2006), and when note-takers are low in WMC and do not have the capacity to take the benefit of note-taking (Kiewra & Benton, 1988). These negative aspects of note-taking may arise from the features of the passage. Note-taking can hinder comprehension when the passage is heard slow rather than fast, which conflicts with the finding that note-taking in the L2 requires a large amount of cognitive effort (Piolat et al., 2005) and faster speech interferes with listening comprehension in L2 (e.g., Rosenhouse et al., 2006). Comprehension can be hampered by note-taking when the passage is long (longer than 5 minutes) rather than when it is short (shorter than 2 minutes and a half), and when the content is familiar to the note-takers than when it is less familiar (Carrell et al., 2002).

On the other hand, note-taking helps listening comprehension when a passage is presented only once (e.g., Chaudron et al., 1994; Lin, 2006). When note-takers are “allowed” to take notes, rather than urged, they can have time to determine when to take notes while listening (Lin, 2006). As mentioned earlier, taking notes while

listening to a faster (Lin, 2006), shorter and less familiar passage (Carrell et al., 2002), can facilitate note-takers' performance on the following comprehension task (Song, 2012).

It was considered that investigating bilinguals in their (near) everyday situation would shed light on the cognitive mechanism of speech comprehension, although in the DL paradigm, both reaction times (cf. Jäncke et al., 1992) and note-taking have not been often considered, possibly due to the instantaneous nature of the stimuli (e.g., syllable pairs) and the way they are recalled (i.e., orally, e.g., Penner et al., 2009). Hence, note-taking was encouraged in the following three experiments. Note-taking was introduced as an experimental manipulation to consider the ways in which bilinguals use their languages in their daily life, and investigate practical aspects of the cognitive mechanism of speech comprehension of passages among bilinguals under the near real-life situation (although admittedly the BDL paradigm is laboratory-based). It was also thought that note-taking, which involves a number of cognitive processes (Piolat et al., 2005) subserved by the central executive component of working memory (Baddeley, 2000), would improve the understanding of the effects of semantic relatedness, attended language, and unattended language on the cognitive mechanism of bilingual speech comprehension assessed in the BDL task.

The effect of note-taking was also considered on ear preference (i.e., preferred or non-preferred) and attentional control so as to examine whether note-taking would enhance comprehension through both preferred (between Experiments 1 and 4) and non-preferred (between Experiments 2 and 5) ears, whether comprehension in the preferred ear would be also better than that in the non-preferred ear when note-taking was allowed (between Experiments 4 and 5), and whether note-taking would influence the degree of ear advantage (i.e., REA) (between Experiments 3 and 6). These comparisons were made in order to substantiate the effects of ear preference and note-taking on the investigations of the cognitive mechanism of bilingual speech comprehension. It was predicted that note-taking would enhance maintenance of attention to the target language and inhibition of linguistic and semantic interference

from the non-target language, thereby leading to better comprehension. Every effort was made to collect an equal number of participants who have equal L2 proficiency and WMC in each of the following three experiments to the previous three experiments in order to obtain comparable data.

6.2 Experiment 4

Experiment 4 was conducted to observe differences, if any, in the effects of semantic relatedness, attended language, and unattended language on bilingual speech comprehension compared to those in Experiment 1. Results from Experiment 4 are compared with those of Experiment 1 to investigate the effect of note-taking on bilingual speech comprehension in the preferred ear, aiming to obtain data for better understanding of these fixed effects on and the roles of individual differences factors in bilingual speech comprehension. The results from Experiment 4 are further compared with those of Experiment 5 to probe the effect of ear preference when note-taking is encouraged.

6.2.1 Methods

Experimental design, methods, and procedure employed in Experiment 4 were exactly the same as in Experiment 1 except that the participants were different individuals from those in Experiment 1. They were told that they were allowed to take notes and it was their choice not to do so. An A4 sheet with sixteen spaces, one for each of sixteen pairs of passages, was provided for notes.

6.2.2 Participants

50 Japanese-English bilinguals (31 females) took part in the experiment in return for a reward. All of them were right-handed, with normal or corrected-to-normal vision and reported no hearing disabilities. A half of them were undergraduate and

Table 6.1. *Participants' Gender, Cognitive, and Experiential Characteristics (Experiment 4)*

Gender	English Proficiency	WMC ^b	Age	AoA ^c	LoL ^d
M: 19, F: 31	21.98 (4.46) B2-C1 ^a	2.51 (.576)	24.44 (5.74)	10.68 (3.37)	12.37 (5.28)
Ear Preference ^e	Universities ^f				
R: 33, L: 17	Tokyo Gakugei University (Tokyo) and the University of Edinburgh (UK)				

Note. M: Males, F: Females. R: Right, L: Left. Standard deviations are presented in parentheses.

^a Scales indicated in the Common European Framework of References scales (Council of Europe, 2001). Max = 30

^b Max = 5.0

^c Age of L2 acquisition.

^d Length of L2 learning.

^e R: Right, L: Left.

^f Universities where the participants were collected.

postgraduate students at the University of Edinburgh and the other half at Tokyo Gakugei University, Tokyo. The length of stay in the UK among the students from the University of Edinburgh was two months on average (ranging from one month to seventeen months, *Mean* = 2.32, *SD* = 5.74). In the following analysis, it was found that the effect of location (i.e., where they were collected) was not significant, *beta* = -0.073, *SE* = 0.070, *p* = .2958, meaning that their performance in the BDL task was not significantly different. The details of the participants are summarised in Table 6.1.

6.2.3 Results

Most of the participants in Experiment 4 took notes for all sixteen passages presented to their preferred ear. Some of the participants left a few spaces in the A4 sheet for notes blank probably because a few passages were too difficult for them and they could not comprehend them, decide what to write down, and produce notes within the time limit. On the other hand, a few did not take notes at all probably because

Table 6.2. *Mean Comprehension Scores of English and Japanese of the Semantically Related and Unrelated Passages in Each Condition (Experiment 4)*

		Attended Language			
		English		Japanese	
		Unattended Language		Unattended Language	
		English	Japanese	English	Japanese
Semantic Relatedness	Related	.68 (.698)	.77 (.771)	2.70 (.953)	2.43 (.985)
	Unrelated	1.04 (.914)	.79 (.783)	2.84 (1.00)	2.92 (.976)

Note. $N = 50$. Standard deviations are presented in parentheses.

they were high in proficiency and WMC note-taking was not a big help for them or even disruptive for them or, on the contrary, because they were low in proficiency and WMC they were unable to comprehend the passage, decide what to write down, and produce notes nearly simultaneously. Characteristics of the notes varied individually. Some produced notes that were decipherable not only for themselves but also for others. Their notes seemed to be condensed and included mostly keywords. Others produced notes that may be only readable for them. Their notes, on the contrary, included many sentences without enough keywords that could be used to answer comprehension questions.

Means of comprehension in each language in each condition are shown in Table 6.2 with standard deviations in parentheses. Results of the GLMM of comprehension of English and Japanese are summarised in Tables 6.3 and 6.4 (see Appendix D.1), respectively. As the principal purpose of Experiment 4 was to find whether the effects of semantic relatedness, attended language, and unattended language, as demonstrated in Experiment 1, would occur when participants could take notes, this section presents results with brief discussion.

Table 6.3. *Coefficients (betas), Standard Errors (SEs), and p Values for Generalised Linear Mixed Models of Listening Comprehension in the BDL Task (Experiment 4)*

Fixed Effects	Comprehension		
	<i>beta</i>	<i>SE</i>	<i>p</i>
(Intercept) ^a	-0.291	0.071	0.0001***
Semantic relatedness (unrelated)	0.143	0.053	0.0075**
Attended language (Japanese)	1.200	0.063	0.0001***
Unattended language (Japanese)	0.007	0.053	0.8945 (ns)
WMC	0.120	0.058	0.0376*
L2 proficiency (residual)	0.015	0.008	0.0488*
Random Effect	Variance		
Participants	0.020165		

^a Model assumes baseline is a pair of semantically related passages, with English as the attended language and English as the unattended language.

* $p < .05$, ** $p < .01$, *** $p < .0001$

Effects of semantic relatedness, attended language and unattended language

There was a significant main effect of semantic relatedness, $\beta = 0.143$, $SE = 0.053$, $p < .01$, with better comprehension of the semantically unrelated passages than that of semantically related passages ($Mean = 1.898$, $SE = .082$; $Mean = 1.645$, $SE = .065$, respectively). As expected, a highly significant main effect of attended language, $\beta = 1.200$, $SE = 0.063$, $p < .001$, with better comprehension when the attended language is Japanese than when it is English was found ($Mean = 2.723$, $SE = .090$; $Mean = .820$, $SE = .084$, respectively). A main effect of unattended language was not significant, $\beta = 0.007$, $SE = 0.053$, $p = .8945$, meaning that information

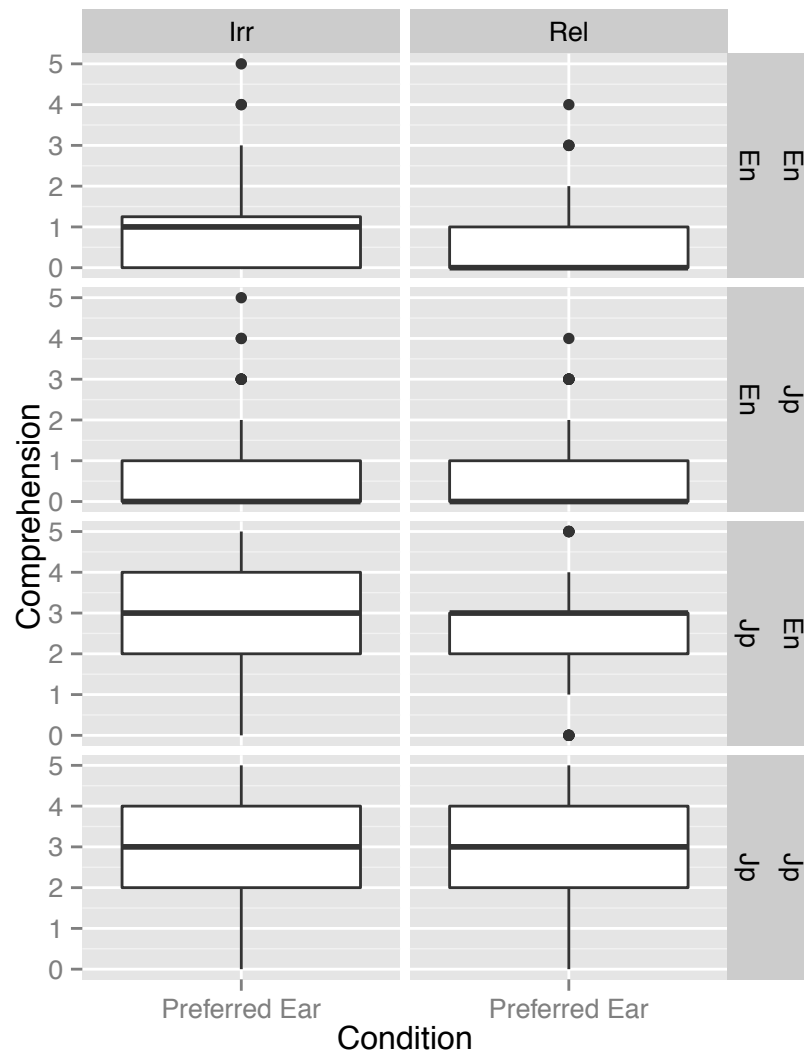


Figure 6.1. Boxplots showing the interquartile ranges of comprehension scores for conditions of the semantically related passages (REE, REJ, RJE, and RJJ) and the semantically unrelated passages (UREE, UREJ, URJE, and URJJ) (Experiment 4). Rel refers to semantically related and Irr to semantically unrelated. En: English; Jp: Japanese. The first label in the row name refers to the attended languages and the second label in the row name refers to the unattended languages. Condition denotes that the participants used their preferred ear. Medians are presented with the thick horizontal bars. Dots in the figure represent data points that are outside of the 95% confidence interval, which is shown by the vertical lines extending beyond the first and third quartile hinges.

from the unattended language did not have an effect on comprehension of the attended language (Unattended Japanese: $Mean = 1.728$, $SE = .079$; Unattended

English: $Mean = 1.815$, $SE = .068$). No significant two- and three-way interactions between semantic relatedness, attended language, and unattended language were found (semantic relatedness*attended language, $beta = -0.297$, $SE = 0.179$, $p = .0963$, semantic relatedness*unattended language, $beta = -0.399$, $SE = 0.224$, $p = .0747$, attended language*unattended language, $beta = -0.074$, $SE = 0.189$, $p = .6966$, and semantic relatedness*attended language*unattended language, $beta = 0.376$, $SE = 0.255$, $p = .1399$).

Although 66% (33 out of 50) of the current participants chose their right ear as their preferred (attended) ear and 34% (17 out of 50) chose their left ear as their preferred ear, the effect of attended ear, whether left or right, as the preferred ear was not significant, $beta = 0.037$, $SE = 0.071$, $p = .6034$. Although the participants were collected in two different locations, the effect of location was not significant, $beta = -0.073$, $SE = 0.070$, $p = .2958$, meaning that their performance in the BDL task was not different depending on their location.

Comparisons between the four conditions within each language (i.e., between REE, REJ, UREE, and UREJ, and between RJE, RJJ, URJE, and URJJ) showed only one significant difference, which was between REE and UREE (UREE ($Mean: 1.04$) > REE ($Mean: .68$), $beta = 0.425$, $SE = 0.156$, $p < .01$), meaning that semantically unrelated English was much less interfering with comprehension of English than semantically related English. No other state-comparisons were significant among the pairs of passages with English as the attended language and those with Japanese as the attended language (see Table 6.4 in Appendix D.1 and Figure 6.1).

Individual differences factors

Results of the GLMM with Poisson error distribution where comprehension of each state is the dependent variable, WMC, and L2 proficiency are fixed factors, and participants is the random effect, are shown in Table 6.2. Effects of the other individual differences factors were found to be non-significant, hence, they were not included in the final model.

As a result, overall comprehension of both L1 and L2 was found to be positively related to WMC ($\beta = 0.120$, $SE = 0.058$, $p < .05$) and L2 proficiency ($\beta = 0.015$, $SE = 0.008$, $p < .05$), with WMC contributing more to comprehension. Significant two-way interactions between attended language and L2 proficiency ($\beta = -0.079$, $SE = 0.016$, $p < .001$) and between attended language and WMC ($\beta = -0.371$, $SE = 0.100$, $p < .001$) indicate that these cognitive factors contribute more to the processing of L2 than that of L1. The rest of the experiential factors and exposures to each language were also non-significant, hence, they were not included in the final model.

6.3 Cross-experimental analyses between Experiments 1 and 4

The effect of note-taking, whether it was not allowed or encouraged, for processing bilinguals' two languages when their attention is directed to one language in one ear (preferred ear) and there is another language (either L1 or L2) in the other ear, and when these languages are semantically related and unrelated, was investigated in the same GLMM in which the effect of note-taking was included as a fixed effect.

6.3.1 Results and Discussion

Results of the GLMM are shown in Table 6.5. Fixed effects and interactions that were found to be significant are shown in the table, but they are not discussed extensively as the main interest is to find the significance of the effect of note-taking and interactions between note-taking and other fixed effects.

There was a significant effect of note-taking, $\beta = 0.127$, $SE = 0.051$, $p < .05$, suggesting that note-taking enhances maintenance of attention to one language and inhibition of semantic and linguistic interferences from another language (With notes: $Mean = 1.949$, $SE = .061$; Without notes: $Mean = 1.771$, $SE = .061$) in the preferred ear. Two-way interactions between note-taking and attended ear ($\beta = 0.119$, $SE = 0.099$, $p = .2275$), semantic relatedness ($\beta = 0.010$, $SE = 0.249$, $p = .$

Table 6.5. *Coefficients (betas), Standard Errors (SEs), and p Values for Generalised Linear Mixed Models of Listening Comprehension in the BDL Task (Experiments 1 and 4)*

Fixed Effects	Comprehension		
	<i>beta</i>	<i>SE</i>	<i>p</i>
(Intercept) ^a	-0.446	0.060	0.0001***
NoteTaking: With Notes	0.127	0.051	0.0132*
Semantic relatedness (related)	-0.117	0.039	0.0028**
Attended language (Japanese)	1.372	0.050	0.0001***
Unattended language (Japanese)	0.027	0.039	0.4847 (ns)
WMC	0.074	0.035	0.0357*
L2 proficiency	0.079	0.011	0.0001***
Exposure (reading in English)	-0.037	0.017	0.0281*
Exposure (listening in English)	0.047	0.020	0.0200*
Exposure (speaking in English)	-0.064	0.024	0.0074**
Attended language (Japanese)*L2 proficiency	-0.074	0.011	0.0001***
Random Effect	Variance		
Participants	0.010597		

^a Model assumes baseline is a pair of semantically unrelated passages, with English as the attended language presented to the preferred ear and English as the unattended language to the other ear, without note-taking.

* $p < .05$, ** $p < .01$, *** $p < .0001$

9666), attended language ($beta = -0.150$, $SE = 0.181$, $p = .4089$), and unattended language ($beta = -0.230$, $SE = 0.229$, $p = .3160$), were not significant. For other significant fixed effects, please see Table 6.5.

The effect of note-taking was not due to the differences in L2 proficiency ($beta = 0.004$, $SE = 0.011$, $p = .7471$), WMC ($beta = 0.073$, $SE = 0.068$, $p = .2800$), AoA

($\beta = 0.001$, $SE = 0.015$, $p = .9249$), and LoL ($\beta = -0.002$, $SE = 0.012$, $p = .8674$). No interactions between note-taking and the other individual differences factors were significant, hence not shown in the table, suggesting that the better performance when note-taking is encouraged is not due to the differences in cognitive and experiential factors (Exposure (reading in L1): $\beta = -0.023$, $SE = 0.032$, $p = .4730$; Exposure (listening in L1): $\beta = -0.005$, $SE = 0.014$, $p = .7145$; Exposure (writing in L1): $\beta = 0.025$, $SE = 0.032$, $p = .4393$; Exposure (speaking in L1): $\beta = -0.032$, $SE = 0.025$, $p = .2152$; Exposure (reading in L2): $\beta = 0.037$, $SE = 0.033$, $p = .2647$; Exposure (listening in L2): $\beta = 0.022$, $SE = 0.038$, $p = .5585$; Exposure (writing in L2): $\beta = 0.078$, $SE = 0.058$, $p = .1797$; Exposure (speaking in L2): $\beta = 0.071$, $SE = 0.053$, $p = .1800$).

A four-way interaction between note-taking, semantic relatedness, attended language, and unattended language was not significant, $\beta = -0.272$, $SE = 0.389$, $p = .4857$. No three-way interactions between these fixed effects reached significance.

Practical aspects of bilingual speech comprehension

The BDL stimuli used in the current experiments were short (one minute), included less familiar topics, and fast (English: 172.45 words per minute; Japanese: 411.53 characters per minute), for which the participants could take the benefit from note-taking. In addition, they were not forced, but allowed to take notes. With these conditions appropriate for benefiting voluntary note-taking, remarks as for the practical aspects of the cognitive mechanism of speech comprehension can be made.

The main finding from the cross-experimental analyses is that note-taking indeed enhances comprehension and it does not influence the other processes (i.e., semantic relatedness, attended and unattended languages), although the latter conclusion awaits results from Experiments 5 and 6, and cross-experimental analyses between Experiments 2 and 5, and 3 and 6.

The current cross-experimental analyses verify that bilinguals have the ability to sustain their attention to one language while suppressing interference from another

familiar language, that may be semantically related or unrelated to the attended language, when they are in the form of passages that are usually encountered in a natural listening environment (e.g., Bloomfield et al., 2010; Shook & Marian, 2013). It is argued that this is what is taking place when bilinguals comprehend speech since this cognitive and language control is routinely required when listening to even only one of their languages, as when hearing one language, the other language is also activated and has to be efficiently inhibited (e.g., Crinion et al., 2006; Dijkstra, 2005; Jared & Kroll, 2001; Kroll & Dussias, 2013; Marian & Spivey, 2003a, 2003b; Thierry & Wu, 2007; Weber, 2001).

Furthermore, these bilingual listening behaviours, i.e., maintenance of attention to the relevant language, suppression of the irrelevant language, and resolution of language and semantic competition, all of which happening in the brain, are subserved by the functions of WMC, that are dividing attention (e.g., Baddeley et al., 2001; Colflesh & Conway, 2007; Engle, 2002), maintaining attention to the task goal (e.g., Conway & Engle, 1994; Engle & Kane, 2004; Engle et al., 1999), inhibiting task-irrelevant information (e.g., Elliott, 2002; Engle et al., 1999; Engle & Kane, 2004; Ilkowska & Engle, 2010; Osaka & Osaka, 2007), and resolving conflicts (e.g., Osaka et al., 2004; Rodriguez-Fornells, et al., 2006; Wang et al., 2009). These cognitive functions are fulfilled through the favourable ear-to-hemisphere route (i.e., preferred ear, whether left or right), and performances are enhanced by voluntary note-taking.

6.4 Summary and Conclusions

The cross-experimental analysis between Experiment 1 where note-taking was not allowed and Experiment 4 where note-taking was allowed, in both of which preferred ear was used, aimed to investigate the practical aspects of the cognitive mechanism of bilingual speech comprehension by inspecting whether note-taking would facilitate or hinder bilinguals' listening performance in the BDL task. It was found that bilinguals in fact show enhanced listening behaviours through their

favourable ear-to-hemisphere route when note-taking is allowed than when it is prevented. This would suggest that the voluntary note-taking, that is a spontaneous behaviour among listeners in everyday situations (Piolat et al., 2005), indeed facilitates maintenance of attention to one language and suppression of another, those of which include unavoidable concurrent language (e.g., Crinion et al., 2006) and semantic competition (e.g., Badre et al., 2005), which in fact native listeners would not experience under normal listening conditions (Weber & Cutler, 2004).

Under the pseudo real-life listening condition where both language and semantic competition are manipulated to occur simultaneously, the current results have also shown that L2 proficiency and WMC are crucially required for resolving conflicts between languages and semantic information (e.g., Craik & Bialystok, 2006; Emmorey et al., 2008, Green, 1998).

The current results are in agreement with the previous studies in that note-taking enhances listening comprehension of the attended language (e.g., Lin, 2006), and further demonstrate that the unattended language is more inhibited when note-taking is available that seems to be a natural listening environment (e.g., Bloomfield et al., 2010) than when it is not. It has been shown that listening comprehension, which involves resolution of semantic and language competition, is enhanced when note-taking is in concert with high L2 proficiency and WMC (e.g., Emmorey et al., 2008; Kiewra & Benton, 1988).

The real-life listening environment indeed contains not only language information, but also non-linguistic sounds such as vehicles, wind, and rain, and they are not only auditory but also visual. Therefore, further research with the BDL task is clearly needed to reveal how bilingual listeners manage to get through these adverse real-life listening situations (e.g., Adank et al., 2012; Cooke et al., 2008; Mattys et al., 2009; Romei et al., 2011; Van Engen, 2010).

The next section presents results of Experiment 5 where non-preferred ear was used, but note-taking was allowed, and comparisons between Experiments 2 and 5 to investigate the effect of note-taking in the non-preferred ear and between

Experiments 4 and 5 to examine the effect of ear preference when note-taking was allowed.

6.5 Experiment 5

Experiment 5 was conducted to observe differences, if any, in the effects of semantic relatedness, attended language, and unattended language on bilingual speech comprehension compared to those in Experiment 2. Results from Experiment 5 are compared with those of Experiment 2 to investigate the effect of note-taking on bilingual speech comprehension in the non-preferred ear, aiming to obtain data for better understanding of these fixed effects on and the roles of individual differences factors in bilingual speech comprehension. The results from Experiment 5 are further compared with those of Experiment 4 to probe the effect of ear preference when note-taking is encouraged.

6.5.1 Methods

Experimental design, methods, and procedure employed in Experiment 5 were exactly the same as in Experiment 2 except that the participants were different individuals from those in Experiment 2. They were told that they were allowed to take notes and it was their choice not to do so. An A4 sheet with sixteen spaces, one for each of sixteen pairs of passages, was provided for notes, as in Experiment 4.

6.5.2 Participants

50 Japanese-English bilinguals (26 females) took part in the experiment in return for a reward. All of them were right-handed, with normal or corrected-to-normal vision and reported no hearing disabilities. A half of them were undergraduate and postgraduate students at the University of Edinburgh and the other half at Tokyo Gakugei University, Tokyo. The length of stay in the UK among the students from the University of Edinburgh was three months on average (ranging from one month to twenty months, *Mean* = 3.50, *SD* = 6.54). In the following analysis, it was found that the effect of location (i.e., where they were collected) was not significant, *beta* =

Table 6.6. *Participants' Gender, Cognitive, and Experiential Characteristics (Experiment 5)*

Gender	English Proficiency	WMC ^b	Age	AoA ^c	LoL ^d
M: 24, F: 26	21.00 (4.29) B2-C1 ^a	2.51 (.576)	21.33 (2.99)	10.42 (3.31)	10.99 (4.29)
Ear Preference ^e	Universities ^f				
R: 29, L: 21	Tokyo Gakugei University (Tokyo) and the University of Edinburgh (UK)				

Note. M: Males, F: Females. R: Right, L: Left. Standard deviations are presented in parentheses.

^a Scales indicated in the Common European Framework of References scales (Council of Europe, 2001). Max = 30

^b Max = 5.0

^c Age of L2 acquisition.

^d Length of L2 learning.

^e R: Right, L: Left.

^f Universities where the participants were collected.

0.049, $SE = 0.070$, $p = .4887$, meaning that their performance in the BDL task was not significantly different. During the BDL task, they were asked to use their *non-preferred* ear, the opposite ear indicated in the earedness questionnaire. Twenty-nine (13 females) used their left ear as their non-preferred ear (meaning their preferred ear was their right ear).

6.5.3 Results

Means of comprehension in each language in each condition are shown in Table 6.7 with standard deviations in parentheses. Results of the GLMM of comprehension of English and Japanese are summarised in Tables 6.8. As the principal purpose of Experiment 5 was to find whether the effects of semantic relatedness, attended language, and unattended language, as demonstrated in Experiment 2, would occur when participants could take notes, this section presents results with brief discussion.

Table 6.7. *Mean Comprehension Scores of English and Japanese of the Semantically Related and Unrelated Passages in Each Condition (Experiment 5)*

		Attended Language			
		English		Japanese	
		Unattended Language		Unattended Language	
		English	Japanese	English	Japanese
Semantic Relatedness	Related	.99 (.696)	1.06 (.733)	2.90 (.808)	2.50 (.985)
	Unrelated	1.03 (.906)	1.03 (.779)	3.02 (.920)	3.06 (.946)

Note. $N = 50$. Standard deviations are presented in parentheses.

Effects of semantic relatedness, attended language and unattended language

A main effect of semantic relatedness was not found significant ($\beta = 0.089$, $SE = 0.051$, $p = .0806$), meaning that using the non-preferred ear prevents one from processing semantic information (Related passages: $Mean = 1.658$, $SE = .041$; Unrelated passages: $Mean = 1.743$, $SE = .041$). A main effect of unattended language was not also found significant ($\beta = -0.037$, $SE = 0.051$, $p = .4627$), indicating that not only semantic but also linguistic information from the unattended ear did not influence the processing of the attended language in the non-preferred ear (Unattended Japanese: $Mean = 1.661$, $SE = .044$; Unattended English: $Mean = 1.739$, $SE = .042$). As expected, a significant main effect of attended language was found ($\beta = 1.027$, $SE = 0.057$, $p < .001$), suggesting that comprehension of Japanese is better than that of English (Japanese: $Mean = 2.635$, $SE = .062$; English: $Mean = 0.765$, $SE = .048$). No significant two- and three-way interactions between semantic relatedness, attended language, and unattended language were found (semantic relatedness*attended language, $\beta = 0.001$, $SE = 0.163$, $p = .9954$, semantic relatedness*unattended language, $\beta = -0.068$, $SE = 0.197$, $p = .7292$, attended language*unattended language, $\beta = -0.217$, $SE = 0.164$, $p = .1870$, and semantic relatedness*attended language*unattended language, $\beta = 0.230$, $SE = 0.230$, $p = .3179$) (see Figure 6.2).

Table 6.8. *Coefficients (betas), Standard Errors (SEs), and p Values for Generalised Linear Mixed Models of Listening Comprehension in the BDL Task (Experiment 5)*

Fixed Effects	Comprehension		
	<i>beta</i>	<i>SE</i>	<i>p</i>
(Intercept) ^a	-0.005	0.061	0.9310 (ns)
Semantic relatedness (unrelated)	0.089	0.051	0.0806(.)
Attended language (Japanese)	1.027	0.057	0.0001***
Unattended language (Japanese)	-0.037	0.051	0.4627 (ns)
WMC	-0.048	0.054	0.3770 (ns)
L2 proficiency	0.018	0.006	0.0040**
Exposure (reading in L1)	0.058	0.024	0.0142*
Exposure (writing in L1)	-0.088	0.034	0.0101*
Random Effect	Variance		
Participants	2.40E-13		

^a Model assumes baseline is a pair of semantically related passages, with English as the attended language and English as the unattended language.
(.) $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .0001$

Although 58% (29 out of 50) of the current participants chose their left ear as their non-preferred (attended) ear and 42% (21 out of 50) chose their right ear as their non-preferred ear, the effect of attended ear, whether left or right, as the non-preferred ear was not significant, $beta = 0.066$, $SE = 0.056$, $p = .2352$. Hence, the results of comprehension in the BDL task in Experiment 5 were not due to the choice of the attended ear. Although the participants were collected in two different locations, the effect of location was not significant, $beta = 0.049$, $SE = 0.070$,

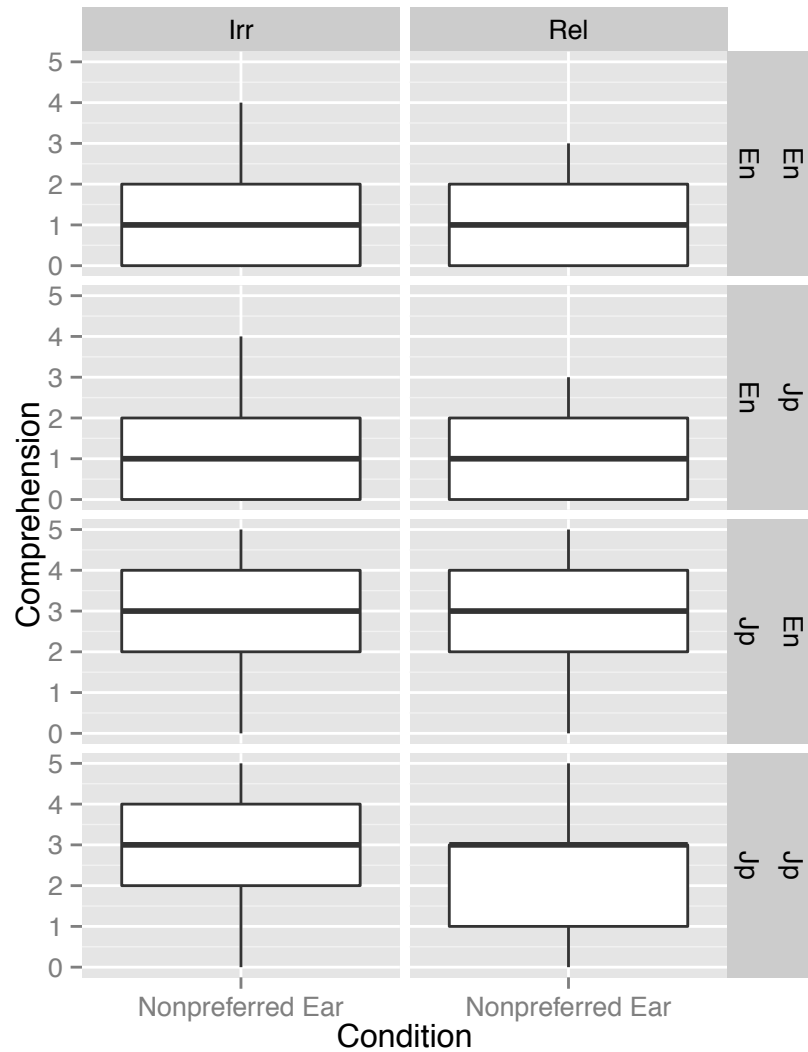


Figure 6.2. Boxplots showing the interquartile ranges of comprehension scores for conditions of the semantically related passages (REE, REJ, RJE, and RJJ) and the semantically unrelated passages (UREE, UREJ, URJE, and URJJ) (Experiment 5). Rel refers to semantically related and Irr to semantically unrelated. En: English; Jp: Japanese. The first label in the row name refers to the attended languages and the second label in the row name refers to the unattended languages. Condition denotes that the participants used their non-preferred ear. Medians are presented with the thick horizontal bars. Dots in the figure represent data points that are outside of the 95% confidence interval, which is shown by the vertical lines extending beyond the first and third quartile hinges.

$p = .4887$, meaning that their performance in the BDL task was not different depending on their location.

Individual differences factors

Results of the GLMM with Poisson error distribution where comprehension of each state is the dependent variable, WMC, L2 proficiency, Exposures (reading in L1 and writing in L1) are fixed factors, and participants is the random effect, are shown in Table 6.6. Effects of the other individual differences factors were found to be non-significant, hence, they were not included in the final model.

L2 proficiency was found to significantly contribute to comprehension when non-preferred ear was used and note-taking was encouraged, $\beta = 0.018$, $SE = 0.006$, $p < .01$, whereas contribution of WMC was not significant, $\beta = -0.048$, $SE = 0.054$, $p = .3770$. The amount of reading in L1 was positively related to comprehension ($\beta = 0.058$, $SE = 0.024$, $p < .05$; $Mean = 2.13$ hours, $SD = 2.27$, 9.74% of the total amount of time in L1 and L2), whereas the amount of writing in L1 was negatively related to comprehension ($\beta = -0.088$, $SE = 0.034$, $p < .05$; $Mean = 1.38$ hours, $SD = 1.59$, 6.31% of the total amount of time in L1 and L2). The rest of the experiential factors and exposures to each language were also non-significant, hence, they were not included in the final model.

6.6 Cross-experimental analyses between Experiments 2 and 5

The effect of note-taking, whether it was not allowed or encouraged, for processing bilinguals' two languages when their attention is directed to one language in one ear (non-preferred ear) and there is another language (either L1 or L2) in the other ear, and when these languages are semantically related and unrelated, was investigated in the same GLMM in which the effect of note-taking was included as a fixed effect.

6.6.1 Results and Discussion

Results of the GLMM are shown in Table 6.9. Fixed effects and interactions that were found to be significant are shown in the table, but they are not discussed

Table 6.9. *Coefficients (betas), Standard Errors (SEs), and p Values for Generalised Linear Mixed Models of Listening Comprehension in the BDL Task (Experiments 2 and 5)*

Fixed Effects	Comprehension		
	<i>beta</i>	<i>SE</i>	<i>p</i>
(Intercept) ^a	-0.445	0.058	0.0001***
NoteTaking: With Notes	0.256	0.049	0.0001***
Semantic relatedness (related)	-0.050	0.038	0.193 (ns)
Attended language (Japanese)	1.325	0.049	0.0001***
Unattended language (Japanese)	-0.046	0.038	0.235 (ns)
WMC	0.031	0.036	0.378 (ns)
L2 proficiency	0.084	0.010	0.0001***
Attended language (Japanese)* L2 proficiency	-0.092	0.011	0.0001***
Random Effect	Variance		
Participants	0.004729		

^a Model assumes baseline is a pair of semantically unrelated passages, with English as the attended language presented to the non-preferred ear and English as the unattended language to the other ear, without note-taking.
*** $p < .0001$

extensively as the main interest is to find the significance of the effect of note-taking and interactions between note-taking and other fixed effects.

There was a significant effect of note-taking, $\beta = 0.256$, $SE = 0.049$, $p < .001$, suggesting that note-taking enhances maintenance of attention to one language and inhibition of semantic and linguistic interferences from another language (With notes: $Mean = 1.949$, $SE = .052$; Without notes: $Mean = 1.451$, $SE = .052$) in the non-preferred ear. Overall comprehension of both L1 and L2 both when note-taking was

not allowed and encouraged, was found to depend not on the degrees of WMC ($\beta = 0.031$, $SE = 0.036$, $p = .378$), but on the degrees of L2 proficiency ($\beta = 0.084$, $SE = 0.010$, $p < .001$). The effect of note-taking was not different between attended ears, $\beta = -0.072$, $SE = 0.086$, $p = .399$, in comprehension between semantically related and unrelated passages, $\beta = 0.115$, $SE = 0.242$, $p = .6361$, between attended languages, $\beta = -0.104$, $SE = 0.193$, $p = .5896$, and between unattended languages, $\beta = 0.470$, $SE = 0.257$, $p = .0672$.

The effect of note-taking was not due to the differences in L2 proficiency ($\beta = 0.008$, $SE = 0.011$, $p = .460$), WMC ($\beta = -0.115$, $SE = 0.070$, $p = .102$), AoA ($\beta = -0.001$, $SE = 0.013$, $p = .950$), and LoL ($\beta = 0.001$, $SE = 0.011$, $p = .903$). A negative two-way interaction between note-taking and Exposure (writing in L1) was found, $\beta = -0.060$, $SE = 0.030$, $p < .05$, meaning that the amount of writing in L1 negatively influences listening performance when note-taking is allowed. No interactions between note-taking and the other individual differences factors were significant, suggesting that the better performance when note-taking is encouraged is not due to the differences in cognitive and experiential factors (Exposure (reading in L1): $\beta = -0.017$, $SE = 0.021$, $p = .437$; Exposure (listening in L1): $\beta = -0.005$, $SE = 0.009$, $p = .590$; Exposure (speaking in L1): $\beta = -0.016$, $SE = 0.023$, $p = .494$; Exposure (reading in L2): $\beta = 0.028$, $SE = 0.045$, $p = .530$; Exposure (listening in L2): $\beta = 0.009$, $SE = 0.028$, $p = .748$; Exposure (writing in L2): $\beta = 0.032$, $SE = 0.074$, $p = .666$; Exposure (speaking in L2): $\beta = 0.042$, $SE = 0.059$, $p = .478$).

A four-way interaction between note-taking, semantic relatedness, attended language, and unattended language was not significant, $\beta = 0.548$, $SE = 0.392$, $p = .1616$. A three-way interaction between note-taking, semantic relatedness, and unattended language was marginally significant, $\beta = -0.658$, $SE = 0.350$, $p = .0603$. No other three-way interactions between these fixed effects reached significance.

6.7 Summary and Conclusions

The cross-experimental analyses between Experiment 2 where note-taking was not allowed and Experiment 5 where note-taking was allowed, in both of which non-preferred ear was used, aimed to find the effect of note-taking on bilingual speech comprehension in the non-preferred ear. As a result, note-taking has been found to assist the non-preferred ear with comprehension of one language while suppressing another that vary in the degrees of semantic relationships. Note-taking did not influence the degrees of semantic and language competition from the unattended ear, meaning that the unfavourable ear-to-hemisphere route plausibly does not efficiently resolve semantic and language competition, although it is difficult to interpret a null effect.

The current results show the importance of WMC not only when goal-related information must be actively maintained to guide response selection (i.e., attended language), especially if contextually inappropriate response alternatives (i.e., unattended language) are also available (e.g., Conway & Engle, 1994; Engle & Kane, 2004), but also when the deprivation of external memory occurs (Experiment 2) along with this situation with concurrent competition, although note-taking incurs considerable cognitive resources (Piolat et al., 2005).

The next section presents cross-experimental analyses between Experiments 4 and 5 to compare the effect of the favourable ear-to-hemisphere route and the unfavourable one on maintenance of attention to one language and inhibition of another while overcoming semantic and language competition, when the external memory is available.

6.8 Cross-experimental analyses between Experiments 4 and 5

The effect of ear preference, whether left or right, for processing bilinguals' two languages when their attention is directed to one language and there is another language (either L1 or L2) in the other ear, and when these languages are

semantically related and unrelated, was investigated in the same GLMM in which the effect of ear preference was included as a fixed effect.

6.8.1 Results and Discussion

Results of the GLMM are shown in Table 6.10. Fixed effects and interactions that were found to be significant are shown in the table, but they are not discussed extensively as the main interest is to find the significance of the effect of ear preference.

A significant main effect of ear preference (Condition) was found, $\beta = -0.129$, $SE = 0.044$, $p < .01$, suggesting that maintaining attention to one language and inhibiting semantic and linguistic interferences from another language is, unexpectedly, better accomplished in the non-preferred ear than in the preferred ear (Non-preferred ear: $Mean = 1.949$, $SE = .057$; Preferred ear: $Mean = 1.771$, $SE = .065$). This result is discussed later in detail.

Overall comprehension of both L1 and L2 in both the preferred and non-preferred ears was found not to depend on the degrees of WMC ($\beta = 0.105$, $SE = 0.081$, $p = .1987$), but on L2 proficiency ($\beta = 0.079$, $SE = 0.010$, $p < .001$). Significant two-way interactions between attended language and L2 proficiency and WMC means that both L2 proficiency and WMC contribute more to comprehension of L2 than to that of L1, $\beta = -0.080$, $SE = 0.011$, $p < .001$, and $\beta = -0.215$, $SE = 0.074$, $p < .01$, respectively. Another significant two-way interaction between Condition and WMC indicates an explicit link between them with a positive direction of the effect of WMC towards the use of the preferred ear, $\beta = 0.166$, $SE = 0.081$, $p < .05$, suggesting that executive control is best achieved through the preferred ear-to-hemisphere route. The link was not observed between Condition and L2 proficiency, $\beta = -0.001$, $SE = 0.010$, $p = .9343$.

The effect of ear preference was not subject to the differences in L2 proficiency ($\beta = -0.001$, $SE = 0.010$, $p = .9343$), AoA ($\beta = -0.012$, $SE = 0.014$, $p = .3911$), and LoL ($\beta = -0.004$, $SE = 0.008$, $p = .6753$). No interactions between Condition

Table 6.10. *Coefficients (betas), Standard Errors (SEs), and p Values for Generalised Linear Mixed Models of Listening Comprehension in the BDL Task (Experiments 4 and 5)*

Fixed Effects	Comprehension		
	<i>beta</i>	<i>SE</i>	<i>p</i>
(Intercept) ^a	-0.051	0.056	0.3620 (ns)
Condition: Preferred ear	-0.129	0.044	0.0036**
Attended ear: Right	0.037	0.045	0.4200 (ns)
Semantic relatedness (related)	-0.114	0.037	0.0019**
Attended language (Japanese)	1.175	0.045	0.0001***
Unattended language (Japanese)	-0.016	0.037	0.6605 (ns)
WMC	0.105	0.081	0.1987 (ns)
L2 proficiency	0.079	0.010	0.0001***
Condition (Preferred ear)*WMC	0.166	0.081	0.0398*
Attended language (Japanese)*WMC	-0.215	0.074	0.0040**
Attended language (Japanese)*L2 proficiency	-0.080	0.011	0.0001***
Random Effect	Variance		
Participants	0.011495		

^a Model assumes baseline is a pair of semantically unrelated passages, with English as the attended language presented to the non-preferred ear and English as the unattended language to the other ear.

* $p < .05$, ** $p < .01$, *** $p < .0001$

and the other individual differences factors were significant, suggesting that the better performance in the non-preferred ear is not due to the differences in cognitive and experiential factors (Exposure (listening in L1): $beta = 0.006$, $SE = 0.010$, $p = .5970$; Exposure (reading in L1): $beta = -0.007$, $SE = 0.026$, $p = .7956$; Exposure (writing in L1): $beta = 0.048$, $SE = 0.027$, $p = .0768$; Exposure (speaking in L1):

$\beta = -0.061$, $SE = 0.033$, $p = .0673$; Exposure (listening in L2): $\beta = -0.000$, $SE = 0.018$, $p = .9907$; Exposure (reading in L2): $\beta = -0.014$, $SE = 0.027$, $p = .5957$; Exposure (writing in L2): $\beta = 0.010$, $SE = 0.036$, $p = .7836$; Exposure (speaking in L2): $\beta = -0.034$, $SE = 0.024$, $p = .1658$).

A four-way interaction between Condition, semantic relatedness, attended language, and unattended language was not significant, $\beta = -0.146$, $SE = 0.344$, $p = .6700$.

Better performance through the unfavourable route

Unexpectedly, when an external memory is available, listening performance has been found to be better through the unfavourable ear-to-hemisphere route than through the favourable route. Although it is entirely speculative, the participants in Experiment 5 became more careful in their non-preferred ear and attempted to make the most of note-taking, hence, their performance turned out to be better than those who used their preferred ear after all. On the other hand, the participants who used their preferred ear in Experiment 4 may have become careless because they were allowed to use their preferred ear and take notes.

In Experiment 4, more semantic processing might have been performed among the participants because they were allowed to take notes, which might have inversely interfered with the processing of the attended language. Whereas in Experiment 5, with the un-automatised route, extra effort was necessary to attend to the non-preferred ear, that might have more effectively prevented interference from the unattended language, along with the help of note-taking, leading to overall better performance. There may have been unexamined factors that affected the effect of preferred ear in Experiment 4 and non-preferred ear in Experiment 5.

The next section attempts to inspect what might have caused these differences by comparing Experiments 1, 2, 4, and 5.

6.9 Cross-experimental analyses between Experiments 1, 2, 4, and 5

A cross-experimental analysis between Experiments 1, 2, 4 and 4 was conducted in the same GLMM. Participants were a random effect (random intercepts only), and note-taking (treatment coded: with notes vs. without notes; without notes = baseline), ear preference (treatment coded: preferred ear vs. non-preferred ear; non-preferred ear = baseline), semantic relatedness (treatment coded: semantically related vs. unrelated; semantically unrelated = baseline), attended language (treatment coded: English vs. Japanese; English = baseline), and unattended language (treatment coded: English vs. Japanese; English = baseline) were fixed effects. L2 proficiency and WMC were also included as fixed effects.

Results of the GLMM of comprehension of English and Japanese are summarised in Tables 6.11. There was a significant effect of note-taking with higher performance when note-taking is allowed, $\beta = 0.268$, $SE = 0.048$, $p < .001$. The effect of ear preference was not significant, $\beta = 0.034$, $SE = 0.047$, $p = .4689$, suggesting that the use of the preferred ear does not always facilitate comprehension. As has been observed across the four experiments, effects of semantic relatedness and attended language were significant, $\beta = -0.083$, $SE < .01$, and $\beta = 1.273$, $SE = 0.033$, $p < .001$, respectively, meaning that semantically unrelated passages were better comprehended than semantically related passages, and comprehension of Japanese was better than that of English. Both L2 proficiency and WMC were found to significantly contribute to overall comprehension, $\beta = 0.014$, $SE = 0.004$, $p < .001$, and $\beta = 0.065$, $SE = 0.026$, $p < .05$, respectively. A significant two-way interaction between note-taking and ear preference, $\beta = -0.151$, $SE = 0.063$, $p < .05$, confirms that note-taking is more interfering when preferred ear is used than when non-preferred ear is used.

These results demonstrate that comprehension differences between semantically related and unrelated passages seem larger when preferred ear is used and note-taking is allowed (Experiment 4) than when non-preferred ear is used and note-taking is allowed (Experiment 5), and when note-taking is not allowed in both ear

Table 6.11. *Coefficients (betas), Standard Errors (SEs), and p Values for Generalised Linear Mixed Models of Listening Comprehension in the BDL Task (Experiments 1, 2, 4, and 5)*

Fixed Effects	Comprehension		
	<i>beta</i>	<i>SE</i>	<i>p</i>
(Intercept) ^a	-0.392	0.047	0.0001***
NoteTaking: With Notes	0.268	0.048	0.0001***
Condition: Preferred ear	0.034	0.047	0.4689 (ns)
Semantic relatedness (related)	-0.083	0.027	0.0025**
Attended language (Japanese)	1.273	0.033	0.0001***
Unattended language (Japanese)	-0.010	0.027	0.7228 (ns)
NoteTaking(With Notes)* Condition (Preferred Ear)	-0.151	0.063	0.0159*
WMC	0.065	0.026	0.0110*
L2 proficiency	0.014	0.004	0.0001***
Random Effect	Variance		
Participants	0.010222		

^a Model assumes baseline is a pair of semantically unrelated passages, with English as the attended language presented to the non-preferred ear and English as the unattended language to the other ear, without note-taking.

* $p < .05$, ** $p < .01$, *** $p < .0001$

preference conditions (Experiments 1 and 2). This would suggest that note-taking in fact negatively influences listening performance when combined with preferred ear.

The current results show that note-taking in general facilitates bilingual speech comprehension as each of the BDL stimulus was presented once (e.g., Chaudron et al., 1994; Lin, 2006) and the participants were not forced, but “allowed” to take notes (Lin, 2006). Note-taking can, however, hinder comprehension through the favourable

ear-to-hemisphere route, that is counterintuitive. The future research is expected to find unexamined factors that might have influenced speech processing through the preferred ear and explore further the relationship between note-taking and the favourable ear-to-hemisphere route for better understanding of the cognitive mechanism of bilingual speech comprehension in everyday situations.

6.10 Experiment 6

Experiment 6 was conducted to observe differences, if any, in the effects of attended channel, attended language, and unattended language on bilingual speech comprehension compared to those in Experiment 3. Results from Experiment 6 are compared with those of Experiment 3 to investigate the effect of note-taking on auditory attentional control in bilingual speech comprehension, aiming to obtain data for better understanding of these fixed effects on and the roles of individual differences factors in bilingual speech comprehension. The results from Experiment 6 are further compared with those of Experiment 7 to probe the effect of predictability of language switching.

6.10.1 Methods

Experimental design, methods, and procedure employed in Experiment 6 were exactly the same as in Experiment 3 except that the participants were different individuals from those in Experiment 3. They were encouraged to take notes during the BDL task.

6.10.2 Participants

116 Japanese-English bilinguals (78 females) took part in the experiment in return for a reward. All of them were right-handed, with normal or corrected-to-normal vision and reported no hearing disabilities. The details of the participants are summarised in Table 6.12.

6.10.3 Results and Discussion

Means of comprehension in each language in each condition are shown in Table 6.13 with standard deviations in parentheses. Results of the GLMM of comprehension of

Table 6.12. *Participants' Gender, Cognitive, and Experiential Characteristics (Experiment 6)*

Gender	English Proficiency	WMC ^b	Age	AoA ^c	LoL ^d
M: 38, F: 78	18.66 (3.55) B2-C1 ^a	2.74 (.770)	20.25 (1.60)	10.29 (2.57)	9.49 (2.80)
Ear Preference ^e	Universities ^f				
R: 66, L: 29, B: 17	Tokyo Gakugei University (Tokyo), Hokkaido University of Education, Hakodate (Hokkaido), Senshu University (Kanagawa), and Showa Women's University (Tokyo).				

Note. M: Males, F: Females. R: Right, L: Left. Standard deviations are presented in parentheses.

^a Scales indicated in the Common European Framework of References scales (Council of Europe, 2001). Max = 30

^b Max = 5.0

^c Age of L2 acquisition.

^d Length of L2 learning.

^e R: Right, L: Left, B: Both. The remaining four participants did not answer the questionnaire.

^f Universities where the participants were collected.

English and Japanese are summarised in Tables 6.14 and 6.15 (see Appendix D.2), respectively. As the principal purpose of Experiment 6 was to find whether the effects of attended channel, attended language, and unattended language, as demonstrated in Experiment 3, would occur when participants could take notes, this section presents results with brief discussion.

Effects of attended channel, attended language, and unattended language

There was a significant main effect of attended channel ($\beta = 0.328$, $SE = 0.094$, $p < .001$), with better comprehension of passages heard in the right ear than in the left ear ($Mean = 2.056$, $SE = .054$; $Mean = 1.957$, $SE = .045$, respectively) (see Figure 6.3). As expected, a significant main effect of attended language, $\beta = 1.367$, $SE = 0.051$, $p < .001$, with better comprehension when the attended language is Japanese

Table 6.13. *Mean Comprehension Scores of English and Japanese in the Left Ear and Right Ear in Each Condition (Experiment 6)*

		Attended Language			
		English		Japanese	
Attended Channel		Unattended Language		Unattended Language	
		English	Japanese	English	Japanese
	Left	.84 (.699)	1.04 (.741)	3.09 (.869)	2.85 (.725)
	Right	1.17 (.878)	1.01 (.791)	2.84 (1.15)	3.20 (1.03)

Note. $N = 116$. Standard deviations are presented in parentheses.

than when it is English was found ($Mean = 2.997$, $SE = .053$; $Mean = 1.016$, $SE = .050$, respectively). There was another significant main effect of unattended language, $beta = 0.207$, $SE = 0.096$, $p < .05$, with better comprehension when the unattended language is Japanese than when it is English ($Mean = 2.025$, $SE = .047$; $Mean = 1.988$, $SE = .052$, respectively). Although 60.344% (70 out of 116) of the current participants chose their right ear, 25% (29 out of 116) their left ear, and 14.655% (17 out of 116) their both ears as their preferred ear (i.e., earedness), the effects of earedness, between left and right, $beta = -0.046$, $SE = 0.044$, $p = .3013$, between left and both, $beta = -0.011$, $SE = 0.059$, $p = .8544$, and right and both, $beta = -0.035$, $SE = 0.055$, $p = .5233$, were not significant. Hence, the results of comprehension in the BDL task in Experiment 6 were not due to the participants' earedness.

Two-way interactions between attended channel and attended language ($beta = -0.411$, $SE = 0.108$, $p < .001$), between attended channel and unattended language ($beta = -0.357$, $SE = 0.131$, $p < .01$), and between attended language and unattended language ($beta = -0.286$, $SE = 0.110$, $p < .01$) were all significant. The participants comprehended Japanese better than English in both ears (Right ear, Japanese: $Mean = 3.022$, $SE = .075$ vs. English: $Mean = 1.091$, $SE = .060$; Left ear, Japanese: $Mean = 2.972$, $SE = .058$ vs. English: $Mean = .942$, $SE = .054$) and comprehended each language better in the right ear than in the left ear (English, Right ear: $Mean = 1.091$,

Table 6.14. *Coefficients (betas), Standard Errors (SEs), and p Values for Generalised Linear Mixed Models of Listening Comprehension in the BDL Task (Experiment 6)*

Fixed Effects	Comprehension		
	<i>beta</i>	<i>SE</i>	<i>p</i>
(Intercept) ^a	-0.179	0.072	0.0128*
Attended channel (right)	0.328	0.094	0.0004***
Attended language (Japanese)	1.297	0.081	0.0001***
Unattended language (Japanese)	0.207	0.096	0.0319*
Attended channel*Attended language	-0.411	0.108	0.0001***
Attended channel*Unattended language	-0.357	0.131	0.0065**
Attended language*Unattended language	-0.286	0.110	0.0094**
Attended channel* Attended language*Unattended language	0.554	0.152	0.0001***
WMC	-0.056	0.023	0.0142*
L2 proficiency (residual)	0.025	0.005	0.0001***
Exposure (reading in L1)	0.037	0.011	0.0001***
Exposure (writing in L1)	-0.031	0.015	0.0362*
Random Effect	Variance		
Participants	0.0066047		

^a Model assumes baseline is a pair of semantically related passages, with left ear as the attended channel, with Japanese as the attended language and Japanese as the unattended language.

* $p < .05$, ** $p < .01$, *** $p < .0001$

$SE = .060$ vs. Left ear: $Mean = .942$, $SE = .054$; Japanese, Right ear: $Mean = 3.022$, $SE = .075$ vs. Left ear: $Mean = 2.972$, $SE = .058$), regardless of the unattended language. The right-ear advantage was confirmed to be represented in comprehension of both languages.

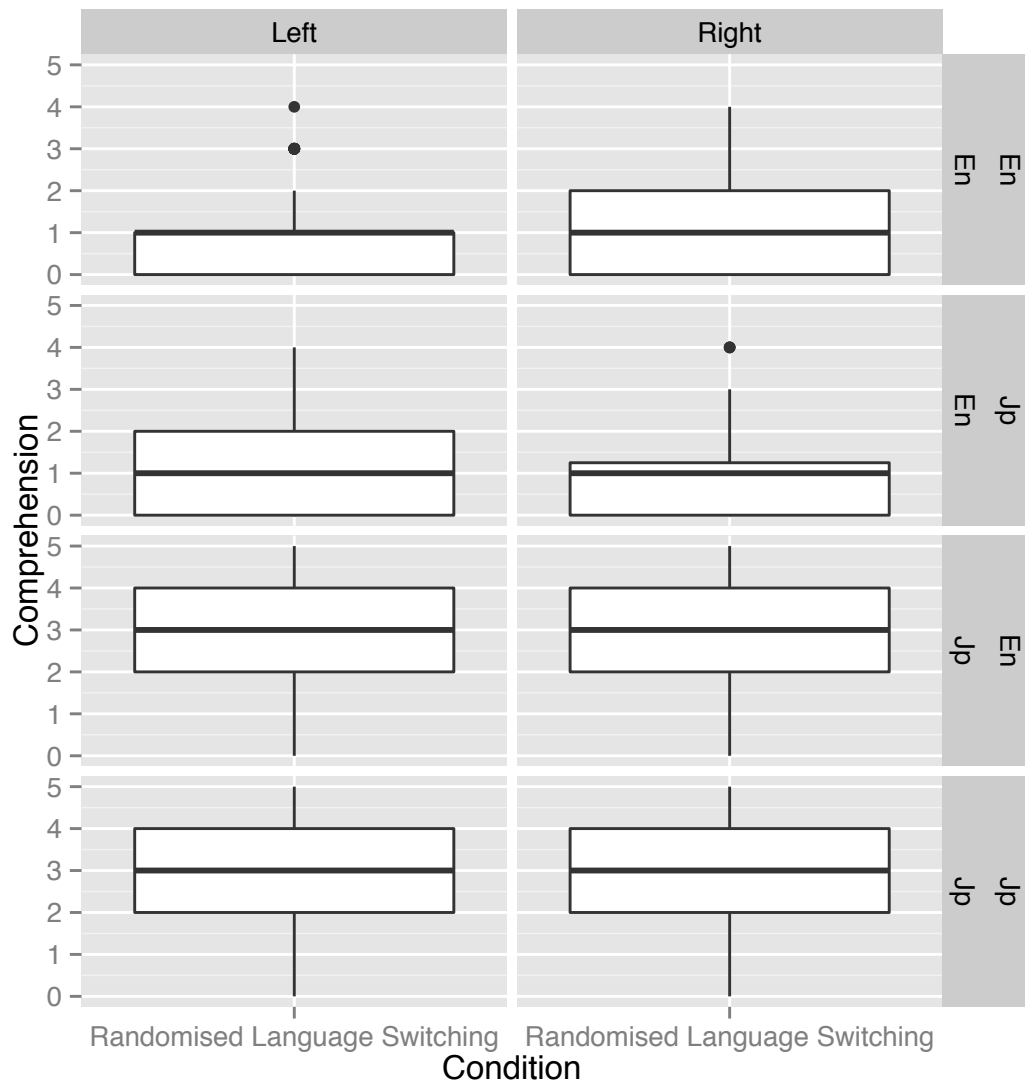


Figure 6.3. Boxplots showing the interquartile ranges of comprehension scores for conditions of the passages presented to the right ear (RTEE, RTEJ, RTJE, and RTJJ) and the passages presented to the left ear (LTEE, LTEJ, LTJE, and LTJJ) (Experiment 6). En: English; Jp: Japanese. The first label in the row name refers to the attended languages and the second label in the row name refers to the unattended languages. Condition denotes that the attended languages were randomly presented. Medians are presented with the thick horizontal bars. Dots in the figure represent data points that are outside of the 95% confidence interval, which is shown by the vertical lines extending beyond the first and third quartile hinges.

When the unattended language was English, comprehension, regardless of the attended language, was better in the right ear (English, Right ear: $Mean = 2.185$, $SE = .068$ vs. Left ear: $Mean = 1.849$, $SE = .052$), but when the unattended language was

Japanese, comprehension was better in the left ear (Japanese, Left ear: *Mean* = 2.065, *SE* = .058 vs. Right ear: *Mean* = 1.927, *SE* = .075), implying that unattended English in the right ear may be more interfering than that in the left ear and unattended Japanese in the left ear may be more interfering than that in the right ear. In the right ear, comprehension was better when the unattended language was English than when it was Japanese (English: *Mean* = 2.185, *SE* = .068 vs. Japanese: *Mean* = 1.927, *SE* = .075), but comprehension in the left ear was better when the unattended language was Japanese than when it was English (Japanese: *Mean* = 2.065, *SE* = .058 vs. English: *Mean* = 1.849, *SE* = .052), indicating that within the right ear unattended Japanese may be more interfering than unattended English and within the left ear unattended English may be more interfering than unattended Japanese.

Comprehension of Japanese was better regardless of unattended language (Unattended English, Japanese: *Mean* = 3.026, *SE* = .060 vs. English: *Mean* = 1.009, *SE* = .057; Unattended Japanese, Japanese: *Mean* = 2.968, *SE* = .069 vs. English: *Mean* = 1.024, *SE* = .058), suggesting that comprehension of Japanese is not interrupted by the requirement to switch between ears and unattended language. When English was the attended language, comprehension was better when Japanese was the unattended language than when it was English (Japanese: *Mean* = 1.024, *SE* = .058 vs. English: *Mean* = 1.009, *SE* = .057), but comprehension of Japanese was better when the unattended language was English than when it was Japanese (English: *Mean* = 3.026, *SE* = .060 vs. Japanese: *Mean* = 2.968, *SE* = .069), meaning that comprehension of one language is interfered with by the same language more than by another language.

The two-way interactions were qualified by a significant three-way interaction between attended channel, attended language, and unattended language, *beta* = 0.554, *SE* = 0.152, *p* < .001. To identify what caused the significant three-way interaction, pairwise comparisons between the eight conditions (i.e., RTEE, RTEJ, RTJE, RTJJ, LTEE, LTEJ, LTJE, and LTJJ) were conducted separately for each condition and the other conditions as in Experiment 2. These comparisons were

conducted using GLMMs in which the same fixed and random effects for the GLMMs used for the final model were included.

Pairwise comparisons (see Table 6.15 in Appendix D.2) showed significant differences between RTEE and LTEE with higher comprehension in RTEE (RTEE (*Mean*: 1.17) > LTEE (*Mean*: .84), $\beta = 0.328$, $SE = 0.094$, $p < .001$), suggesting that the right ear receives less interference from English than the left ear when the attended language is also English. Unexpectedly, higher comprehension in LTEJ (*Mean*: 1.04), although not significant, than comprehension in RTEJ (*Mean*: 1.01), $\beta = -0.029$, $SE = 0.092$, $p = .7483$, and marginally significant higher comprehension in RTEE (*Mean*: 1.17) than comprehension in RTEJ (*Mean*: 1.01), $\beta = -0.150$, $SE = 0.089$, $p = .0918$, was found.

Significant differences in comprehension of Japanese were found between RTJJ and LTJJ with higher comprehension in RTJJ (RTJJ (*Mean*: 3.20) > LTJJ (*Mean*: 2.85), $\beta = 0.114$, $SE = 0.054$, $p < .05$), and between RTJE and RTJJ with higher comprehension in RTJJ (RTJJ (*Mean*: 3.20) > RTJE (*Mean*: 2.84), $\beta = 0.117$, $SE = 0.054$, $p < .05$), suggesting that the right ear receives less interference from Japanese than the left ear when the attended language is also Japanese, and that in the right ear unattended English is more interfering than unattended Japanese heard in the left ear. Unexpectedly, higher comprehension in LTJE (*Mean*: 3.09) than comprehension in LTJJ (*Mean*: 2.85), although not significant, $\beta = -0.080$, $SE = 0.054$, $p = .1391$, and higher comprehension in LTJE (*Mean*: 3.09) than comprehension in RTJE (*Mean*: 2.84), although not significant, $\beta = -0.083$, $SE = 0.054$, $p = .1250$, was found.

No other state-comparisons were significant among the pairs of passages with English as the attended language and those with Japanese as the attended language (see Table 6.15 and Figure 6.3). These unexpected comprehension differences in each attended language may have been the cause of the significant three-way interaction between attended channel, attended language, and unattended language. As for comprehension between ears, it was predicted that comprehension in the right ear would be higher than that in the left ear, however, another language as the

unattended language may have produced the opposite results (i.e., LTEJ > RTEJ and LTJE > RTJE). As for comprehension within ear, it was expected that comprehension with Japanese as the unattended language would be higher, however, it was not the case with comprehension of English in the right ear and comprehension of Japanese in the left ear (i.e., RTEE > RTEJ and LTJE > LTJJ).

A laterality index (LI) based on the formula $[(FR - FL)/(FR + FL)] * 100$, as shown in 5.3.2, was calculated as in Experiment 3. An LI of 2.467 was obtained $([(2.056 - 1.957)/(2.056 + 1.957)] * 100)$. This index is fairly low compared to the LI of 16.12 obtained in Experiment 3. The possible reason for this small LI is discussed after describing a cross-experimental analysis between Experiments 3 and 6 in 6.11. Although a significant effect of attended channel was found, note-taking may have reduced the comprehension differences between the left ear and right ear.

Individual differences factors

Results of the GLMM with Poisson error distribution where comprehension of each state is the dependent variable, WMC, L2 proficiency and Exposures (reading and writing in L1) are fixed factors, and participants is the random effect, are shown in Table 6.14. Effects of the other individual differences factors were found to be non-significant, hence, they were not included in the final model.

Results showed that overall comprehension of both L1 and L2 was dependent on the degrees of WMC ($\beta = -0.056$, $SE = 0.023$, $p < .05$), although negatively, L2 proficiency positively ($\beta = 0.025$, $SE = 0.005$, $p < .001$), Exposure (reading in L1) ($\beta = 0.037$, $SE = 0.011$, $p < .001$), and Exposure (writing in L1) ($\beta = -0.031$, $SE = 0.015$, $p < .05$). These results show that WMC was not found to support the performance much less than expected, instead, L2 proficiency was found to significantly contribute to the performance. As for the experiential factors, the amount of reading in L1 ($Mean = 3.33$ hours, $SD = 2.32$, 13.33% of the total amount of time in L1 and L2) was positively related to the performance, whereas the amount

of writing in L1 ($Mean = 2.36$ hours, $SD = 1.70$, 9.45% of the total amount of time in L1 and L2) was negatively related to the performance.

6.11 Cross-experimental analyses between Experiments 3 and 6

The effect of note-taking, whether it was not allowed or encouraged, for processing bilinguals' two languages when their attention is shifted between ears and directed to one language in one ear while there is another language (either L1 or L2) in the other ear, was investigated in the same GLMM in which the effect of note-taking was included as a fixed effect.

6.11.1 Results and Discussion

Results of the GLMM are shown in Table 6.16. Fixed effects and interactions that were found to be significant are shown in the table, but they are not discussed extensively as the main interest is to find the significance of the effect of note-taking and interactions between note-taking and other fixed effects.

There was a significant effect of note-taking, $beta = 0.444$, $SE = 0.125$, $p < .001$, suggesting that note-taking enhances maintenance of attention to one language and inhibition of linguistic interferences from another language (With notes: $Mean = 2.006$, $SE = .043$; Without notes: $Mean = 1.538$, $SE = .055$) in both ears. A two-way interaction between note-taking and attended channel was not significant, $beta = 0.057$, $SE = 0.161$, $p = .7231$, suggesting that comprehension in the right ear is not particularly better when note-taking is allowed than when note-taking is not allowed. A three-way interaction between note-taking, attended channel, and attended language was significant, $beta = -0.498$, $SE = 0.182$, $p < .01$ (see Table 6.17). It is expected since it has been found that comprehension when note-taking is allowed, comprehension in the right ear, and comprehension in Japanese is all better than comprehension when note-taking is not allowed, comprehension in the left ear, and comprehension of English, respectively. A four-way interaction between note-taking,

Table 6.16. *Coefficients (betas), Standard Errors (SEs), and p Values for Generalised Linear Mixed Models of Listening Comprehension in the BDL Task (Experiments 3 and 6)*

Fixed Effects	Comprehension		
	<i>beta</i>	<i>SE</i>	<i>p</i>
(Intercept) ^a	-0.681	0.101	0.0001***
NoteTaking: With Notes	0.444	0.125	0.0001***
Attended channel (right)	0.271	0.131	0.0391*
Attended language (Japanese)	1.409	0.110	0.0001***
Unattended language (Japanese)	0.038	0.138	0.7831 (ns)
NoteTaking*Attended channel*Attended language	-0.498	0.182	0.0062**
NoteTaking*Attended channel*Attended language*Unattended language	0.591	0.256	0.0210*
WMC	0.075	0.035	0.0311*
L2 proficiency	0.068	0.008	0.0001***
NoteTaking*Attended channel	0.057	0.161	0.7231 (ns)
NoteTaking*WMC	-0.135	0.046	0.0034**
Attended language (Japanese)*L2 proficiency	-0.057	0.008	0.0001***
Random Effect	Variance		
Participants	0.037905		

^a Model assumes baseline is a pair of semantically related passages, with English as the attended language presented to the left ear and English as the unattended language to the right ear, without note-taking.

* $p < .05$, ** $p < .01$, *** $p < .0001$

attended channel, attended language, and unattended language was significant, $\beta = 0.591$, $SE = 0.256$, $p < .05$. No other three-way interactions between these fixed effects reached significance.

Both L2 proficiency and WMC were found to significantly contribute to speech comprehension while switching ears and suppressing within- and between-language competition, whether note-taking is allowed or not, $\beta = 0.075$, $SE = 0.035$, $p < .$

Table 6.17. *Mean Comprehension Scores of English and Japanese in the Left Ear and Right Ear by Function of Note-taking (Experiments 3 and 6)*

		Attended Channel			
		Left		Right	
		Attended Language		Attended Language	
		English	Japanese	English	Japanese
Note-taking	Without	.556 (.049)	1.753 (.077)	.725 (.055)	2.873 (.091)
	With	.930 (.045)	2.966 (.070)	1.077 (.050)	3.013 (.084)

Note. Standard errors are presented in parentheses.

05, and $\beta = 0.068$, $SE = 0.008$, $p < .001$, respectively. A significant two-way interaction between note-taking and WMC, $\beta = -0.135$, $SE = 0.046$, $p < .01$, confirms that WMC has a greater effect on comprehension when note-taking is not allowed than when it is allowed. The results suggest that note-taking may reduce the demand of WMC as seen in Experiment 6. A significant two-way interaction between attended language and L2 proficiency means that L2 proficiency contributes to comprehension of L2 to a greater extent than comprehension of L1, $\beta = -0.057$, $SE = 0.008$, $p < .001$.

The effect of note-taking was negatively related to Exposure (speaking in L1) ($\beta = -0.044$, $SE = 0.021$, $p < .05$, $Mean = 4.71$ hours, $SD = 2.28$), meaning that the amount of speaking in L1 does not assist the function of note-taking. The effect of note-taking was not due to the differences in L2 proficiency ($\beta = -0.003$, $SE = 0.011$, $p = .7925$), AoA ($\beta = -0.020$, $SE = 0.014$, $p = .1615$), and LoL ($\beta = -0.003$, $SE = 0.014$, $p = .8349$). No interactions between note-taking and the other individual differences factors were significant, suggesting that the better performance when note-taking is encouraged is not due to the differences in cognitive and experiential factors (Exposure (reading in L1): $\beta = 0.022$, $SE = 0.012$, $p = .0596$; Exposure (listening in L1): $\beta = 0.010$, $SE = 0.009$, $p = .2949$; Exposure (writing in L1): $\beta = -0.004$, $SE = 0.026$, $p = .8781$; Exposure (reading in L2): $\beta = -0.036$, $SE = 0.045$, $p = .4223$; Exposure (listening in L2): $\beta = -0.039$, $SE = 0.038$,

$p = .3052$; Exposure (writing in L2): $\beta = -0.030$, $SE = 0.060$, $p = .6194$; Exposure (speaking in L2): $\beta = -0.037$, $SE = 0.073$, $p = .6192$).

Practical aspects of bilingual attentional control

Note-taking was introduced as an experimental manipulation to consider the ways in which bilinguals listen to their languages in their daily life while voluntarily taking notes, and investigate practical aspects of attentional control in speech comprehension among bilinguals under the near real-life situation.

In the BDL task for Experiments 3 and 6, the participants were required to maintain their attention to the task-relevant stimuli (i.e., the stimulus in the attended channel) while suppressing interferences from another language happening simultaneously in the brain (i.e., the stimulus in the other channel). Hence, both attentional control and executive control was thought to be required to achieve the task goal. Attentional control is the capacity to focus and switch attention, whereas executive control is the capacity to monitor and resolve conflicts (e.g., Engle & Kane, 2004; Kane & Engle, 2002; Osaka et al., 2004; Rodriguez-Fornells, et al., 2006; Wang et al., 2009). Additionally, as has been often found in DL studies (e.g., Bryden, 1963; Hugdahl, 2003; Kimura, 1967; Morton et al., 1998; Soveri et al., 2011), the right-ear advantage was expected to be found for processing language presented to the right ear, and inhibiting another language presented to the left ear.

In both Experiments 3 and 6, the REA was found, suggesting that it is in fact easier to comprehend one language in the right ear while overcoming interference from another language in the left ear, whether note-taking is allowed or not. Furthermore, as has been found in cross-experimental analyses between Experiments 1 and 4, and between Experiments 2 and 5, voluntary note-taking has been found to facilitate speech comprehension performance in the BDL task.

Although the effects of attended channel and note-taking were statistically significant, there is another measure that has to be discussed, that is the laterality index (LI), the degree of ear advantage. The LI in Experiment 3 (16.12) was as large

as the one (17.61) found in DL studies by Hugdahl and his colleagues (e.g., Hugdahl, 1995, 2003; Hugdahl & Andersson, 1986), indicating some possibility that the REA found in the BDL task in Experiment 3 may be somewhat compatible with the Hugdahl et al.'s, although the characteristics of the auditory stimuli are largely different, and caution needs to be taken as mentioned in 5.3.7.1.

On the contrary, the LI in Experiment 6, where auditory attentional control in the near real-life situation was attempted to be investigated, was 2.467, indicating that the REA was in fact shrunk by the introduction of note-taking. As note-taking was introduced to consider the ways in which bilinguals use their languages in their daily life, although the effect of attended channel was also significant in Experiment 6, the low LI in Experiment 6 may indicate that in the real-life listening situation the cognitively demanding left ear recall is compensated for by voluntary note-taking while maintaining a stronger advantage of the right ear, leading to almost compatible performance in the left ear (*Mean* = 1.957) to that in the right ear (*Mean* = 2.056). This reduced REA is seen when the stimulus intensity in the left ear is higher than that in the right ear (Westerhausen & Hugdahl, 2010). Nonetheless, the stimulus intensity in each BDL stimulus was remained the same, hence, the reduction in the REA is not due to the volume difference, but to the aid of note-taking.

Unexpectedly, significant roles of executive control (e.g., Engle & Kane, 2004; Kane & Engle, 2002; Osaka et al., 2004; Rodriguez-Fornells, et al., 2006; Wang et al., 2009) in auditory attentional control in comprehension of meaningful passages in the bilinguals' two languages were not found in either experiments, although the effect of WMC was significant on overall comprehension regardless of the help of note-taking. The effect of L2 proficiency was significant in both experiments. On the contrary, the effect of WMC was larger when note-taking was not allowed than when it was allowed. This would mean that higher WMC was not required to switch between ears, maintain attention to one language, and inhibit another in the other ear in the current BDL task, and it was less so when the external memory was voluntarily available.

High WMC does not play its role further in all cognitive tasks such as where more automatised processing is expected than less automatised processing is involved (e.g., Caplan & Waters, 1999; Engle & Conway, 1998). The BDL task clearly involved attentional control (e.g., Alho et al., 2003; Conway & Engle, 1994; Osaka & Osaka, 2007) and both within- and cross-language competition that would require high cognitive inhibitory control (e.g., Abutalebi et al., 2007, 2008; Mercier et al., 2013; Miller & Cohen, 2001). A positive and significant effect of WMC was found in the cross-experimental analysis, but not in the analysis of each experiment.

Brain imaging studies have shown evidence that selection of relevant information in spite of competing semantic information is subserved by the left inferior frontal gyrus (e.g., Thompson-Schill, 2003; Thompson-Schill et al., 1997), where some of the roles of WMC are subserved as well (e.g., Collette & Van der Linden, 2002; Osaka et al., 2004). Hence, it would appear that the lack of semantic competition in the BDL stimuli did not require as much WMC as expected. The more automatised characteristics of processing in the right ear than the left ear and some of the automatised processes in note-taking (e.g., accessing the mental lexicon, and letter information) (Piolat et al., 2005) may have further reduced the demand of WMC for the BDL task. Further research awaits the use of online measures such as PET and fMRI to identify the role of auditory attentional control in comprehension of passages among bilinguals.

6.12 Summary and Conclusions

The cross-experimental analysis between Experiment 3 where note-taking was not allowed and Experiment 6 where note-taking was allowed, in both of which attention shifting was required, was conducted to explore the practical aspects of the cognitive mechanism of bilingual speech comprehension by inspecting whether note-taking would facilitate or hinder bilinguals' auditory attentional control in the BDL task.

The results indicate that note-taking enhances bilinguals' auditory attentional control in comprehension of passages that involve within- and between-language

competition. It was also found that note-taking unexpectedly lowers the demand of WMC and the degree of ear advantage that was indicated by the LIIs. Even when note-taking was not allowed (Experiment 3), only the effect of L2 proficiency was significant, but the effect of WMC was not, implying that the current BDL task where pairs of semantically related passages were presented while the attended channel was switched in an alternating order did not induce any cognitively demanding conflict for the current participants. They may have noticed that the passages were semantically related and attention was shifted in a consistent order, which may have helped them concentrate on the relevant channel and prevented them from using an unnecessary amount of WMC.

The negative effect of WMC appears to be due to the lack of rich semantic competition between the channels (e.g., Osaka et al., 2004; Thompson-Schill, 2003), which was apparently further diminished by the external memory and some of its automatic characteristics (Piolat et al., 2005). The near real-life listening environment established by the BDL task has revealed that auditory attentional control in speech comprehension of passages is not as demanding as expected.

Presentation of the BDL stimuli was counterbalanced, i.e., randomly presented, in Experiments 1, 2, 4, and 5 in order to eliminate any possibility that the participants might expect and prepare to hear the target language because what language to be heard cannot be determined until a bilingual interlocutor starts speaking in the real-life situation. Experiments 3 and 6, where the attended languages were randomly presented, have confirmed a right-ear advantage in processing a passage in one language and blocking another in the other language, regardless of the availability of the external memory. However, it has been uncertain whether language switching patterns, i.e., predictable or unpredictable, influence the bilinguals' auditory attentional control and language control, although this issue in bilingualism needs more empirical attention (e.g., Christoffels et al., 2007; van Hell & Witteman, 2009). Furthermore, processing language switches with different degrees of predictability has been found to lead to different brain activations (e.g., Meuter & Humphreys, 1997; Price et al., 1999; Abutalebi et al., 2007). It was predicted to see differences in

speech comprehension performance in the BDL task depending on the predictability of language switches, as perceiving switches requires auditory attentional control and language control.

The next chapter presents Experiment 7 with a particular focus on bilingual language switching to explore the effect of predictability of language switching on auditory attentional control in bilingual speech comprehension.

CHAPTER 7: LANGUAGE SWITCHING IN BILINGUAL SPEECH COMPREHENSION - EXPERIMENT 7

7.1 Predictability of language switching in speech comprehension

The apparently effortless switching between languages of bilinguals is driven by intricate cognitive mechanisms that are now only beginning to be revealed (van Hell & Witteman, 2009, p. 76). Nevertheless, a majority of research on bilingual language switching has been on word production in a picture/digit naming task or word translation task (e.g., Abutalebi et al., 2012; Hernandez et al., 2000; Meuter & Allport, 1999; Miller & Cohen, 2001; Price et al., 1999; Rodriguez-Fornells et al., 2006; Wang et al., 2007). These results seem to have been overlooked with regard to speech comprehension although a direct link between speech comprehension processes and cognitive control in bilinguals has not yet been established (e.g., Blumenfeld & Marian, 2011).

In studies where language switching in comprehension was examined, the participants were asked to read words and do a semantic categorisation task (e.g., Alvarez et al., 2003; Chauncey et al., 2008; Jackson et al., 2004) or read sentences with final word in a different language from the preceding language (e.g., Moreno et al., 2002; Proverbio et al., 2004). Although contrastive results may have been produced by variations in the participants' language proficiency and learning history, predictability of language switches, the experimental set-up, and whether the tasks were production or comprehension tasks, the ERP technique revealed the temporal unfolding of neural events associated with different subprocesses of language switching (van Hell & Witteman, 2009, p. 69). For example, the amplitude of the N400 was modulated by language switches from L1 to L2 (e.g., Alvarez et al., 2003; Chauncey et al., 2008; Moreno et al., 2002) and it was larger when switching from L1 to L2 than from L2 to L1 (Proverbio et al., 2004). The N400, as explained in Chapter 2, is an index of the integration of meaning and world knowledge (e.g.,

Hagoort et al., 2004; Kutas & Hillyard, 1980), and increases when encountering a semantic incongruency (e.g., Kutas & Hillyard, 1980).

The late positivity complex (LPC) (also known as the P600) is another ERP component that is suggested to reflect sentence-level integration (e.g., Kaan et al., 2000), sentence-level restructuring related to executive control (Kolk & Chwilla, 2007), and processes for memory retrieval (e.g., Pallar & Kutas, 1992). The late positivities indicate the processing of an unexpected task-relevant event (e.g., Coulson et al., 1998) or reconfiguration of stimulus-response mapping (e.g., Moreno et al., 2008). Hence, the LPC demonstrates meaning revision processes when encountering language switches, which are the active preparation of a language switch (van Hell & Witteman, 2009, p. 57). The LPC has been observed in some speech production studies (e.g., Jackson et al., 2001) and comprehension studies (e.g., Moreno et al., 2002), but not in all of the above-mentioned studies (Jackson et al., 2004; Proverbio et al., 2004), which may be due to the variations in the participants and experimental manipulations as explained earlier. The earlier peak latency and smaller amplitude of the LPC among the participants with high L2 proficiency in Moreno et al.'s (2002) study shows that high L2 proficiency enables the bilinguals to notice the language switch earlier than less proficient bilinguals, and the language switch is less unexpected for them and easier to integrate into the sentence structure (van Hell & Witteman, 2009, p. 71).

A few studies that have investigated bilingual language switching in auditory speech comprehension (e.g., Abutalebi et al., 2007; Rinne et al., 2000) demonstrate that it is more difficult to switch from L1 to L2 than from L2 to L1, requiring more cognitive resources (e.g., de Groot & Christoffels, 2006; Meuter et al., 2002). In fact, this is in conflict with the general findings in bilingual language switching in speech production that it is more costly to switch from L2 to L1 (e.g., Green, 1998; Meuter & Allport, 1999), although language switching in both production and comprehension require common executive control areas such as the left caudate (e.g., Crinion et al., 2006), anterior cingulate cortex (ACC) (e.g., Abutalebi et al., 2007; Rodriguez-Fornells et al., 2006; Van Hueven et al., 2008), dorsolateral prefrontal

cortex (DLPFC) (e.g., Holtzheimer et al., 2005; Van Hueven et al., 2008) and superior parietal lobule (SPL) (e.g., Abutalebi et al., 2000; Hernandez, 2009). Abutalebi et al. (2007) ascribe the asymmetrical pattern of switch cost to the nature of their comprehension paradigm. They explain that L1 is not actively inhibited during L2 comprehension, therefore, requiring stronger activation of L2 when switching from L1 to L2.

When individuals are explicitly instructed to speak one language rather than another or to translate from one language into another, the attentional load is arguably less than when they are required to switch unpredictably between languages (Abutalebi & Green, 2008). In other words, *expectations* of which language to speak, whether anticipated or in response to some external cue, also may affect the ease with which a language is selected (e.g., Chee, 2009; Meuter, 2005, p. 358). The effect of predictability of language switches has been exhibited in brain imaging studies. Unpredictable language switches yielded more activation in the frontal lobe area than predictable switches among brain-damaged patients (e.g., Meuter & Humphreys, 1997; Price et al., 1999), which includes areas associated with executive control (e.g., bilateral frontal cortex, bilateral ACC and the right caudate). As the language switches occurred in the sentences used in Abutalebi et al.'s (2007) study were sudden and unpredictable, it would seem that unpredictable switches from L1 to L2 is most difficult to achieve in bilingual speech comprehension, requiring the executive control areas.

Notwithstanding, the influence of predictability of language switches on the ERP components found in these studies including Abutalebi et al.'s (2007) study has yet to be established empirically (Christoffels et al., 2007), although how language switching patterns are modulated by expected versus unexpected language switches is one of the issues that need more empirical attention (van Hell & Wittenman, 2009, p. 77). Furthermore, these previous studies that investigated the effect of order of language switching did not in fact compare the effect of predictable language switches and that of unpredictable switches, but investigated the effect of one or the other. Better performance in the BDL task will be seen when the attended languages

are presented in a predictable order than in an unpredictable order. Hence, the question is: Would the predictability of language switching influence the degree of auditory attentional control and suppression of the unattended language in the BDL task where the participants experience switches from one language to another?

Experiment 7 was conducted to investigate the effect of predictability of language switching on auditory attentional control between channels and resolution of conflicts from the unattended language, by comparing the results with those of Experiment 6. It aimed to obtain data for better understanding of effects of attended channel, attended language, and unattended language on and the roles of individual differences factors in bilingual speech comprehension. In both of these experiments, the participants were allowed to take notes. It is thus predicted that receiving random language switches would be harder than systematic language switches in the BDL task. Hence, those who hear languages in a systematic (i.e., predictable) order would perform better in the BDL task than those who hear languages in a randomised (i.e., unpredictable) order.

The cross-experimental analysis between Experiments 6 and 7 shown below attempts to determine whether the predictability of language switching would influence speech comprehension of passages in one language while shifting between ears and concurrently overcoming interference from another language.

7.1.1 Methods

Experimental design, methods, and procedure employed in Experiment 7 were exactly the same as in Experiment 6 except that the participants were different individuals from those in Experiment 6, and auditory stimuli in the BDL task in Experiment 7 were presented in a systematic order to produce language switches. There were four possible presentation orders (see Appendix E.1) where language switches occurred from L2 to L1 and from L1 to L2 in each ear (i.e., L2 to L1: left ear: *English-Japanese*, *Japanese-Japanese*, *English-English*, *Japanese-Japanese*, *English-Japanese*, *Japanese-English*, *English-English*, and *Japanese-English*; right

ear: *Japanese-English*, *English-Japanese*, *Japanese-English*, *English-English*, *Japanese-Japanese*, *English-Japanese*, *Japanese-Japanese*, and *English-English*. The ones on the left side are attended languages). The attended ear was switched in an alternating order as in Experiment 6 from left to right or from right to left. The unattended languages were presented randomly and in a way that the same language pairs would not be presented consecutively in the same ear. The participants were not told whether the attended languages would be presented in a predictable order. It is likely that they noticed the attended languages were systematically presented as they proceeded with the BDL task.

7.1.2 Participants

98 Japanese-English bilinguals (59 females) took part in the experiment in return for a reward. On average, they started learning English as a second language from about the age of 11 ($Mean = 11.57$, $SD = 2.56$) and had been learning it for 9 years ($Mean = 9.58$, $SD = 2.61$). Their English proficiency was estimated in the same vocabulary section in DIALANG (Alderson & Huhta, 2005) to be between B2 and C1 of the CEFR scales (Council of Europe, 2001) ($Mean = 18.11$, ranging from 12 to 28, $SD = 3.94$, $Max = 30$), WMC in the RST (Osaka & Osaka, 1992) to be 2.82 on average (ranging from 2.0 to 5.0, $SD = .895$, $Max = 5.0$). All of them were right-handed, with normal or corrected-to-normal vision and reported no hearing disabilities. Ear preference was surveyed in the earedness questionnaire with 57 reporting a right-ear preference, 20 reporting a left-ear preference, and 18 reporting a both-ear preference. Three of them did not answer the questionnaire. They were aged between 18 and 34 ($Mean = 20.99$, $SD = 2.09$). They were undergraduate and postgraduate students at Tohoku University, Sendai, Fukushima University, Fukushima, Hokkaido University of Education, Hakodate, and Miyagi Gakuin Women's University, Sendai. The details of the participants are summarised in Table 7.1.

Table 7.1. *Participants' Gender, Cognitive, and Experiential Characteristics (Experiment 7)*

Gender	English Proficiency	WMC ^b	Age	AoA ^c	LoL ^d
M: 39, F: 59	18.11 (3.94) B2-C1 ^a	2.82 (.895)	20.99 (2.09)	11.57 (2.56)	9.58 (2.61)
Ear Preference ^e	Universities ^f				
R: 57, L: 20, B: 18	Tohoku University (Sendai), Fukushima University (Fukushima), Hokkaido University of Education, Hakodate (Hokkaido), and Miyagi Gakuin Women's University (Sendai).				

Note. M: Males, F: Females. R: Right, L: Left. Standard deviations are presented in parentheses.

^a Scales indicated in the Common European Framework of References scales (Council of Europe, 2001). Max = 30

^b Max = 5.0

^c Age of L2 acquisition.

^d Length of L2 learning.

^e R: Right, L: Left, B: Both. The remaining three participants did not answer the questionnaire.

^f Universities where the participants were collected.

7.1.3 Results and Discussion

Means of comprehension in each language in each condition are shown in Table 7.2 with standard deviations in parentheses. Results of the GLMM of comprehension of English and Japanese are summarised in Tables 7.3 and 7.4 (see Appendix E.2), respectively. As the principal purpose of Experiment 7 was to find whether the effects of attended channel, attended language, and unattended language, as demonstrated in Experiment 6, would occur when participants heard languages in a predictable order, this section presents results with brief discussion.

Table 7.2. *Mean Comprehension Scores of English and Japanese in the Left Ear and Right Ear in Each Condition (Experiment 7)*

		Attended Language			
		English		Japanese	
Attended Channel		Unattended Language		Unattended Language	
		English	Japanese	English	Japanese
	Left	.83 (.681)	.86 (.661)	3.07 (.834)	3.15 (.751)
	Right	.99 (.843)	1.16 (.824)	3.23 (1.08)	3.04 (.984)

Note. $N = 98$. Standard deviations are presented in parentheses.

Effects of attended channel, attended language, and unattended language

There was a significant main effect of attended channel ($\beta = 0.174$, $SE = 0.038$, $p < .001$), with better comprehension of passages heard in the right ear than in the left ear ($Mean = 2.107$, $SE = .048$; $Mean = 1.980$, $SE = .041$, respectively) (see Figure 7.1). As expected, a significant main effect of attended language, $\beta = 1.367$, $SE = 0.051$, $p < .001$, with better comprehension when the attended language is Japanese than when it is English was found ($Mean = 3.125$, $SE = .054$; $Mean = .962$, $SE = .051$, respectively). Although 60% (57 out of 95) of the current participants chose their right ear, 21.052% (20 out of 95) their left ear, and 18.947% (18 out of 95) their both ears as their preferred ear (i.e., earedness), the effects of earedness, between left and right, $\beta = 0.029$, $SE = 0.041$, $p = .4787$, between left and both, $\beta = -0.041$, $SE = 0.053$, $p = .4300$, and right and both, $\beta = 0.070$, $SE = 0.044$, $p = .1086$, were not significant. Hence, the results of comprehension in the BDL task in Experiment 7 were not due to the participants' earedness.

Two-way interactions between attended channel and attended language ($\beta = -0.127$, $SE = 0.043$, $p < .01$), and between attended channel and unattended language ($\beta = 0.125$, $SE = 0.052$, $p < .05$) were significant, but a two-way interaction between attended language and unattended language ($\beta = -0.002$, $SE = 0.044$, $p = .9631$) was not significant. The participants comprehended Japanese better than

Table 7.3. *Coefficients (betas), Standard Errors (SEs), and p Values for Generalised Linear Mixed Models of Listening Comprehension in the BDL Task (Experiment 7)*

Fixed Effects	Comprehension		
	<i>beta</i>	<i>SE</i>	<i>p</i>
(Intercept) ^a	-0.201	0.031	0.0001***
Attended channel (right)	0.174	0.038	0.0001***
Attended language (Japanese)	1.311	0.031	0.0001***
Unattended language (Japanese)	0.036	0.039	0.3518 (ns)
Attended channel*Attended language	-0.127	0.043	0.0028**
Attended channel*Unattended language	0.125	0.052	0.0158*
Attended language*Unattended language	-0.002	0.044	0.9631 (ns)
Attended channel* Attended language*Unattended language	-0.221	0.059	0.0002***
WMC	0.090	0.020	0.0001***
L2 proficiency	0.012	0.005	0.0082**
Exposure (listening in L2)	0.029	0.013	0.0215*
Attended channel*WMC	-0.030	0.014	0.0284*
Attended channel*L2 proficiency	0.006	0.003	0.0477*
Random Effect	Variance		
Participants	0.021417		

^a Model assumes baseline is a pair of semantically related passages, with English as the attended language presented to the left ear and English as the unattended language to the right ear.

* $p < .05$, ** $p < .01$, *** $p < .0001$

English in both ears (Right ear, Japanese: *Mean* = 3.138, *SE* = .068 vs. English: *Mean* = 1.077, *SE* = .063; Left ear, Japanese: *Mean* = 3.112, *SE* = .065 vs. English: *Mean* = .847, *SE* = .056) and comprehended each language better in the right ear than in the left ear (English, Right ear: *Mean* = 1.077, *SE* = .063 vs. Left ear: *Mean* =

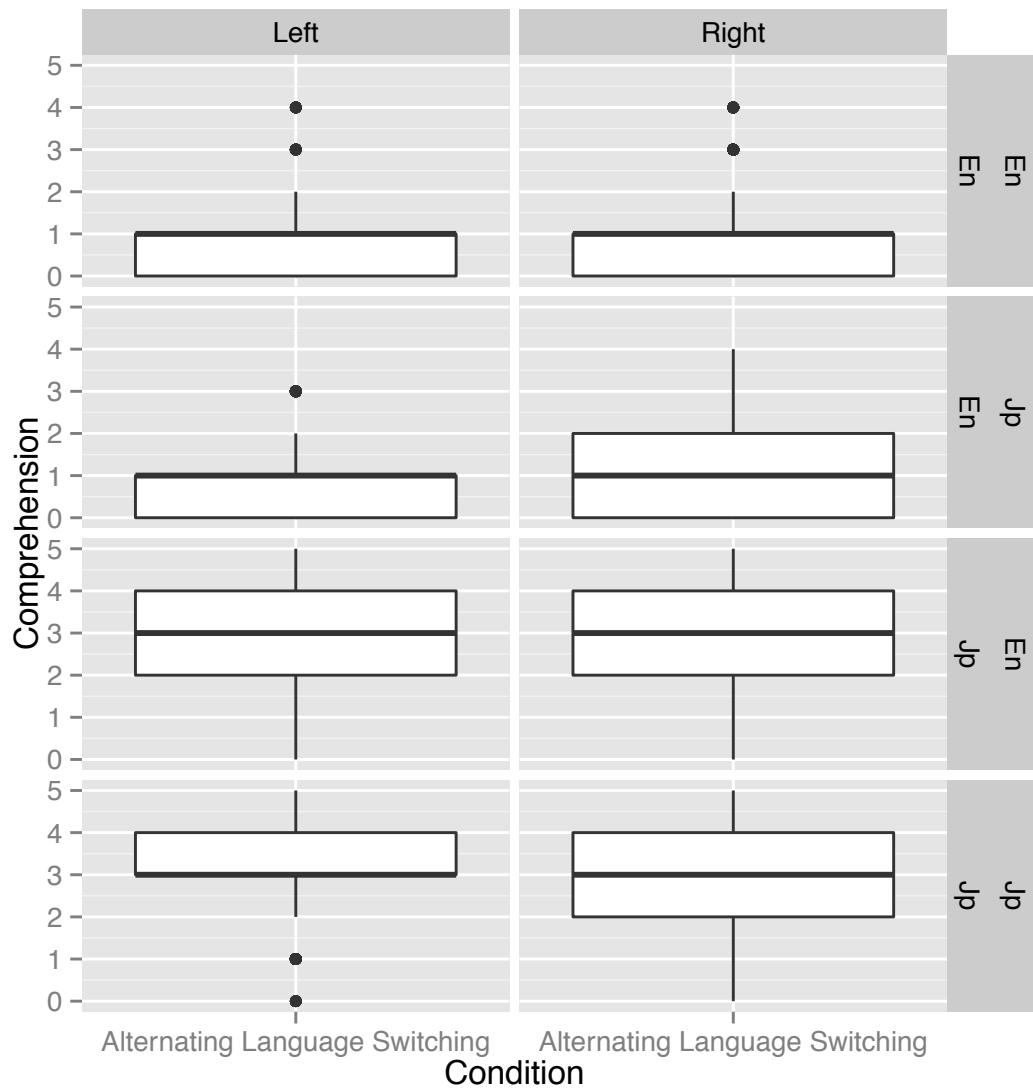


Figure 7.1. Boxplots showing the interquartile ranges of comprehension scores for conditions of the passages presented to the right ear (RTEE, RTEJ, RTJE, and RTJJ) and the passages presented to the left ear (LTEE, LTEJ, LTJE, and LTJJ) (Experiment 7). En: English; Jp: Japanese. The first label in the row name refers to the attended languages and the second label in the row name refers to the unattended languages. Condition denotes that the attended languages were systematically presented. Medians are presented with the thick horizontal bars. Dots in the figure represent data points that are outside of the 95% confidence interval, which is shown by the vertical lines extending beyond the first and third quartile hinges.

.847, $SE = .056$; Japanese, Right ear: $Mean = 3.138$, $SE = .068$ vs. Left ear: $Mean = 3.112$, $SE = .065$), regardless of the unattended language. The right-ear advantage was confirmed for comprehension of both languages.

Regardless of the attended language, when the unattended language was English, comprehension was better in the right ear (English, Right ear: *Mean* = 2.112, *SE* = .060 vs. Left ear: *Mean* = 1.952, *SE* = .055), and when the unattended language was Japanese, comprehension was also better in the right ear (Japanese, Right ear: *Mean* = 2.102, *SE* = .069 vs. Left ear: *Mean* = 2.008, *SE* = .044), indicating that unattended language, whether it is L1 or L2, may be more interfering when attention is paid to the left ear than to the right ear. In the right ear, comprehension was better when the unattended language was English than when it was Japanese (English: *Mean* = 2.112, *SE* = .060 vs. Japanese: *Mean* = 2.102, *SE* = .069), but comprehension in the left ear was better when the unattended language was Japanese than when it was English (Japanese: *Mean* = 2.008, *SE* = .044 vs. English: *Mean* = 1.952, *SE* = .055), indicating that within the right ear unattended Japanese may be more interfering than unattended English and within the left ear unattended English is more interfering than unattended Japanese.

Irrespective of attended channel, comprehension of Japanese was better whether the unattended language was English or Japanese (Unattended English, Japanese: *Mean* = 3.153, *SE* = .072 vs. English: *Mean* = .911, *SE* = .059; Unattended Japanese, Japanese: *Mean* = 3.097, *SE* = .062 vs. English: *Mean* = 1.013, *SE* = .059), suggesting that comprehension of Japanese is not influenced by the unattended language. On the other hand, when English was the attended language, comprehension was better when Japanese was the unattended language than when it was English (Japanese: *Mean* = 1.013, *SE* = .059 vs. English: *Mean* = .911, *SE* = .059), but comprehension of Japanese was better when the unattended language was English than when it was Japanese (English: *Mean* = 3.153, *SE* = .072 vs. Japanese: *Mean* = 3.097, *SE* = .062). Nevertheless, comprehension differences within the same attended language were not statistically significant.

The two-way interactions were qualified by a significant three-way interaction between attended channel, attended language, and unattended language, *beta* = -0.221, *SE* = 0.059, *p* < .001. To identify what caused the significant three-way interaction, pairwise comparisons between the eight conditions (i.e., RTEE, RTEJ,

RTJE, RTJJ, LTEE, LTEJ, LTJE, and LTJJ) were conducted separately for each condition and the other conditions as in Experiment 6 (see Table 7.4 in Appendix E. 2). These comparisons were conducted using GLMMs in which the same fixed and random effects for the GLMMs used for the final model were included.

Pairwise comparisons revealed significant differences between RTEJ and LTEJ with higher comprehension in RTEJ ($\text{RTEJ (Mean: 1.16)} > \text{LTEJ (Mean: .86)}$, $\beta = 0.299$, $SE = 0.102$, $p < .01$), suggesting that attention to the right ear receives less interference from Japanese than the left ear when the attended language is English. It could be that through the advantaged right ear it may be less effortful to inhibit the dominant language heard in left ear than through the left ear inhibiting the dominant language in the right ear. Unexpectedly, the REA was not observed when comparing comprehension in RTEE and that in LTEE ($\text{RTEE (Mean: .99)} \approx \text{LTEE (Mean: .83)}$, $\beta = 0.174$, $SE = 0.106$, $p = .1013$), indicating that comprehension between ears is equal when both attended and unattended languages are English. A marginally significant comprehension difference was found when the unattended language was Japanese between RTEJ and RTEE with higher comprehension in RTEJ ($\text{RTEJ (Mean: 1.16)} > \text{RTEE (Mean: .99)}$, $\beta = 0.161$, $SE = 0.098$, $p = .0983$), implying that unattended Japanese may be less disruptive than unattended English heard in the left ear. Within the left ear, interference from the unattended language, whether it was English or Japanese, was equal ($\text{LTEE (Mean: .83)} \approx \text{LTEJ (Mean: .86)}$, $\beta = 0.036$, $SE = 0.110$, $p = .7419$).

As for comprehension of Japanese, the REA was not found in any comparison ($\text{RTJE (Mean: 3.23)} \approx \text{LTJE (Mean: 3.07)}$, $\beta = 0.047$, $SE = 0.057$, $p = .4100$, and $\text{RTJJ (Mean: 3.04)} \approx \text{LTJJ (Mean: 3.15)}$, $\beta = -0.049$, $SE = 0.057$, $p = .3908$). Significant differences in interference from the unattended language were not also found in any comparison ($\text{LTJE (Mean: 3.07)} \approx \text{LTJJ (Mean: 3.15)}$, $\beta = 0.034$, $SE = 0.057$, $p = .5495$, and $\text{RTJE (Mean: 3.23)} \approx \text{RTJJ (Mean: 3.04)}$, $\beta = -0.062$, $SE = 0.057$, $p = .2787$). These results show that attention to the dominant language is not different between ears and not influenced by the unattended language, whether it is the same or different language.

The unexpected result that the REA was found only in a comparison between RTEJ and LTEJ, that comprehension of Japanese is higher than that of English in any condition, and that the effect of unattended Japanese, although marginal, was found only in a comparison between RTEJ and RTEE, may have caused the negative three-way interaction between attended channel, attended language, and unattended language.

A laterality index (LI) based on the formula $[(FR - FL)/(FR + FL)] * 100$, a relative ear advantage shown by the ratio of the FR (forced-right) performance compared to the FL (forced-left) performance as shown in 5.3.2, was calculated as in Experiment 6. An LI of 3.107 was obtained $([(2.107 - 1.980)/(2.107 + 1.980)] * 100)$. This index is slightly higher than the LI of 2.467 obtained in Experiment 6, but fairly low compared to the LI of 16.12 obtained in Experiment 3. The possible reason for this small LI is discussed after describing a cross-experimental analysis between Experiments 6 and 7 in 7.2. Although a significant effect of attended channel was found, note-taking as shown in Experiment 6 may have reduced the comprehension differences between the left ear and right ear, and predictability of language switches may have increased the REA although to a small extent.

Individual differences factors

Results of the GLMM with Poisson error distribution where comprehension of each state is the dependent variable, WMC, L2 proficiency and Exposure (listening in L2) are fixed factors, and participants is the random effect, are shown in Table 7.3. Effects of the other individual differences factors were found to be non-significant, hence, they were not included in the final model.

It was found that overall comprehension of both L1 and L2 was related to the degrees of WMC ($\beta = 0.090$, $SE = 0.020$, $p < .001$), L2 proficiency ($\beta = 0.012$, $SE = 0.005$, $p < .01$), and Exposure (listening in L2) ($\beta = 0.029$, $SE = 0.013$, $p < .05$). These results indicate that WMC and L2 proficiency play a significant role in auditory attentional control and resolution of both within- and between-language

competition. The only experiential factor, the amount of listening in L2 ($Mean = .985$ hours, $SD = 1.35$, 4.82% of the total amount of time in L1 and L2) was positively related to the performance. Significant two-way interactions between attended right ear and L2 proficiency ($beta = 0.006$, $SE = 0.003$, $p = .0758$) and WMC ($beta = 0.027$, $SE = 0.014$, $p < .05$) show stronger relationships between these cognitive factors and comprehension in the right ear than that in the left ear. Significant two-way interactions between comprehension of English and L2 proficiency ($beta = 0.057$, $SE = 0.004$, $p < .001$), WMC ($beta = 0.041$, $SE = 0.016$, $p < .05$), and Exposure (listening in L2) ($beta = 0.101$, $SE = 0.009$, $p < .001$) indicate stronger relationships between these cognitive and experiential factors and comprehension of English than between comprehension of Japanese. Another significant two-way interaction between unattended English and WMC ($beta = 0.066$, $SE = 0.014$, $p < .001$) indicate better suppression of unattended language when it is English than when it is Japanese, leading to better comprehension of the attended language, whether it is L1 or L2. The rest of the experiential factors and exposures to each language were non-significant, hence, they were not included in the final model.

7.2 Cross-experimental analyses between Experiments 6 and 7

The effect of predictability of language switches, whether it was unpredictable or predictable, for processing bilinguals' two languages when their attention is shifted between ears and directed to one language in one ear while there is another language (either L1 or L2) in the other ear, was investigated in the same GLMM in which the effect of predictability of language switches was included as a fixed effect.

7.2.1 Results and Discussion

Results of the GLMM are shown in Table 7.5. Fixed effects and interactions that were found to be significant are shown in the table, but they are not discussed

Table 7.5. *Coefficients (betas), Standard Errors (SEs), and p Values for Generalised Linear Mixed Models of Listening Comprehension in the BDL Task (Experiments 6 and 7)*

Fixed Effects	Comprehension		
	<i>beta</i>	<i>SE</i>	<i>p</i>
(Intercept) ^a	-0.186	0.079	0.0181*
Condition: Unpredictable	0.005	0.106	0.9598 (ns)
Attended channel (right)	0.174	0.106	0.1015 (ns)
Attended language (Japanese)	1.311	0.088	0.0001***
Unattended language (Japanese)	0.036	0.110	0.7422 (ns)
Predictability*Attended channel	0.154	0.142	0.2786 (ns)
Predictability*Attended language	-0.015	0.120	0.9035 (ns)
Predictability*Unattended language	0.171	0.146	0.2430 (ns)
Predictability*Attended channel*Attended language	-0.283	0.162	0.0804 (.)
Predictability*Attended channel*Unattended language	-0.483	0.197	0.0144*
Predictability*Attended language*Unattended language	-0.284	0.166	0.0862 (.)
Predictability*Attended channel*Attended language*Unattended language	0.775	0.226	0.0006***
WMC	0.067	0.021	0.0011**
L2 proficiency	0.023	0.003	0.0001***
Predictability*WMC	-0.123	0.030	0.0001***
Attended language*L2 proficiency	-0.060	0.007	0.0001***
Random Effect	Variance		
Participants	0.003481		

^a Model assumes baseline is a pair of semantically related passages, with English as the attended language presented to the left ear and English as the unattended language to the right ear with note-taking and predictable language switches.

* $p < .05$, ** $p < .01$, *** $p < .0001$

Table 7.6. *Mean Comprehension Scores of English and Japanese in the Left Ear and Right Ear by Function of Predictability (Experiments 6 and 7)*

		Attended Channel			
		Left		Right	
		Unattended Language		Unattended Language	
		English	Japanese	English	Japanese
Predictability	Unpredictable	1.990 (.063)	1.997 (.056)	2.056 (.072)	2.138 (.068)
	Predictable	2.112 (.060)	2.102 (.069)	1.952 (.055)	2.008 (.044)

Note. Standard errors are presented in parentheses.

extensively as the main interest is to find the significance of the effect of predictability of language switches and interactions between predictability of language switches and other fixed effects.

As a result, the effect of predictability of language switches was not significant, $\beta = 0.005$, $SE = 0.106$, $p = .9598$, meaning that whether the attended language is systematically or randomly presented does not influence speech comprehension performance while controlling attention and suppressing the unattended language (Unpredictable: $Mean = 2.045$, $SE = .047$; Predictable: $Mean = 2.043$, $SE = .038$). A two-way interaction between predictability and attended channel was not significant, $\beta = 0.154$, $SE = 0.142$, $p = .2786$, suggesting that comprehension is not particularly better in one ear than the other when the attended language is systematically presented than when the attended language is randomly presented.

A three-way interaction between predictability, attended channel, and unattended language was significant, $\beta = -0.483$, $SE = 0.197$, $p < .05$ (see Table 7.6). Predictable language switches seem to be better dealt with through the left ear, whereas unpredictable language switches through the right ear. When attended languages were randomly presented, comprehension was better when the unattended language was Japanese in both ears than when it was English. When attended languages were systematically presented, comprehension in the left ear was better when the unattended language was English than when it was Japanese, whereas comprehension in the right ear was better when the unattended language was

Japanese than when it was English. A four-way interaction between predictability, attended channel, attended language, and unattended language was significant, $\beta = 0.775$, $SE = 0.226$, $p < .001$, which would suggest that the three-way interaction shown earlier occurred (or was much stronger) for one attended language relative to the other. No other two- and three-way interactions between these fixed effects reached significance.

Both L2 proficiency and WMC were found to be significantly related to speech comprehension while switching ears and suppressing within- and between-language competition, regardless of predictability of language switches, $\beta = 0.023$, $SE = 0.003$, $p < .001$, and $\beta = 0.067$, $SE = 0.021$, $p < .01$, respectively. A significant two-way interaction between predictability and WMC, $\beta = -0.123$, $SE = 0.030$, $p < .001$, confirms that WMC has a greater effect on comprehension when the attended languages are systematically presented than when they are randomly presented. A significant two-way interaction between attended language and L2 proficiency indicates that L2 proficiency is related to comprehension of L2 to a greater extent than comprehension of L1, $\beta = -0.060$, $SE = 0.007$, $p < .001$.

The effect of predictability of language switches was not due to the differences in L2 proficiency ($\beta = 0.006$, $SE = 0.007$, $p = .3824$) and LoL ($\beta = 0.011$, $SE = 0.009$, $p = .2214$), but was influenced by AoA ($\beta = -0.019$, $SE = 0.010$, $p < .05$), suggesting that the earlier they start learning L2, the better they are able to handle unpredictable language switches. No interactions between predictability of language switches and the other individual differences factors were significant (Exposure (reading in L1): $\beta = 0.020$, $SE = 0.013$, $p = .1220$; Exposure (listening in L1): $\beta = 0.011$, $SE = 0.007$, $p = .1044$; Exposure (writing in L1): $\beta = 0.007$, $SE = 0.017$, $p = .6842$; Exposure (speaking in L1): $\beta = -0.006$, $SE = 0.013$, $p = .6619$; Exposure (reading in L2): $\beta = 0.005$, $SE = 0.027$, $p = .8567$; Exposure (listening in L2): $\beta = -0.011$, $SE = 0.018$, $p = .5468$; Exposure (writing in L2): $\beta = -0.002$, $SE = 0.035$, $p = .9474$; Exposure (speaking in L2): $\beta = -0.049$, $SE = 0.039$, $p = .2099$).

To further explore bilingual attentional control in speech comprehension of passages, the effect of predictability of language switching was considered. As the participants in both Experiments 6 and 7 were allowed to take notes, the only experimental influence on the performance in the BDL task was whether the attended languages were randomly (Experiment 6) or systematically (Experiment 7) presented. It was predicted that knowing what language comes next would help the listeners to better focus on the language and inhibit another language than when they do not know what language comes next.

In both Experiments 6 and 7, the REA was observed, suggesting that it is easier to comprehend one language in the right ear while overcoming interference from another language in the left ear, whether the attended languages were presented in an unpredictable or predictable order. The lack of a significant effect of predictability of language switches may be due to the fact that language switches in the BDL task occurred every two minutes (i.e., one minute for presenting stimuli and one minute for presenting comprehension questions). This long interval may have given the participants enough time to prepare themselves for the next language switch, although during the two minutes they had to listen to one language and inhibit another, and answer comprehension questions. The benefit of predictable language switches may occur more clearly in a task where language switches take place in a short time as has been found in previous studies (e.g., Jackson et al. 2001; Meuter & Allport, 1999; Price, 2010; Price et al., 1999). These studies with words as stimuli reported no switch cost in bilingual speech comprehension, which is in fact *word recognition* (Gollan et al., 2002). Nevertheless, language switches in the previous studies are so rapid that the results cannot provide supporting evidence for the effect of predictability of language switches on *speech comprehension* because there is no rationale for generalisation from single-word processing to the whole language processing and that the isolated words are least candidates for exploring language representation (Paradis, 2003).

The significant three-way interaction between predictability, attended channel, and unattended language may provide some evidence of the effect of predictability of language switches. Better performance in the left ear when language switches are predictable than when they are unpredictable, and better performance in the right ear when language switches are unpredictable than when they are predictable, regardless of attended language, may indicate a better control of unpredictable language switches in the left hemisphere that subserves executive control in bilingual language processing (e.g., Abutalebi et al., 2007; Holtzheimer et al., 2005; Rodriguez-Fornells et al., 2006; Van Hueven et al., 2008) than the right hemisphere. There has been some evidence of more involvement of the right hemisphere, i.e., processing in the left ear, for predictable switches (e.g., Kimberg et al., 2000; Swainson et al., 2003) and more involvement of the left hemisphere, i.e., processing in the right ear, for unpredictable switches (e.g., Erickson et al., 2005; Luks et al., 2002). Nonetheless, a relationship between predictability, attended ear, and WMC in the current experiment was not significant, $\beta = -0.002$, $SE = 0.056$, $p = .9694$, hence, further investigations are necessary with bilinguals with higher WMC, which will also explain another non-significant relationship between predictability, unattended language, and WMC, $\beta = 0.105$, $SE = 0.056$, $p = .0627$.

Predictability of language switches did not largely influence the laterality indices between Experiments 6 ($LI = 2.467$) and 7 ($LI = 3.107$). As explained earlier, because the participants in both experiments were allowed to take notes and the only difference between the two experiments was whether the attended languages were presented randomly or systematically, the small LIs and small difference between the LIs are due to the aid of note-taking and non-significant effect of predictability of language switches.

WMC unexpectedly appears to work better for processing the favourable, seemingly less demanding, characteristics of stimuli (i.e., predictable language switches). This is contrary to the general concept of WMC that WMC is most required when task-relevant information has to be actively maintained to guide response selection, especially when task-irrelevant information is also available

(Engle & Kane, 2004), and to the evidence that unexpected language switches have been found to entail higher attentional load than expected language switches (e.g., Abutalebi & Green, 2008; Rodriguez-Fornells et al., 2002, 2005). This finding, in fact, is similar to the finding in the cross-experimental analyses between Experiments 4 and 5 in that WMC works better through the ‘favourable’ ear-to-hemisphere route than the unfavourable route, whether it is left or right. Although a simple comparison cannot be made between these cross-experimental analyses, there may be strong relationships between WMC and preferred cognitive route (i.e., ear-to-hemisphere route), on one hand, and between WMC and attention to attentionally less effortful (i.e., predictable) stimuli in speech comprehension, on the other.

7.3 Summary and Conclusions

The cross-experimental analysis between Experiment 6 where the attended languages were randomly presented and Experiment 7 where they were systematically presented, in both of which attention shifting was required and note-taking was allowed, was conducted to explore whether predictable language switches would enhance auditory attentional control in bilingual speech comprehension in the BDL task.

The results demonstrate that predictable language switches in fact do not facilitate bilinguals’ speech comprehension that requires concurrent attentional control and suppression of another language. The laterality index in Experiment 7 was not very different from that in Experiment 6, which also indicates no significant influence from predictable language switches on the degree of ear advantage. It could be that the long BDL stimuli reduced and made it difficult to detect the degree of benefits of predictable language switches. Increasing gradually the length of stimuli may help investigate when the effect of predictability of language switches on speech comprehension emerges.

Interestingly, different behaviours were found between left and right ears when processing predictable and unpredictable language switches, with left ear coping

with predictable switches better than unpredictable switches, and with right ear coping with unpredictable switches better than predictable switches. These results are in fact in agreement with previous studies in that unpredictable switches activate the left hemisphere more than the right hemisphere, and predictable switches activate the right hemisphere more than the left hemisphere (e.g., Erickson et al., 2005; Kimberg et al., 2000; Luks et al., 2002; Swainson et al., 2003).

When the attended languages were randomly presented, unattended Japanese was less interfering than unattended English in both attended ears. On the contrary, when the attended languages were systematically presented, unattended Japanese was less interfering than unattended English when attention was shifted to the right ear, whereas unattended English was less interfering than unattended Japanese when attention was shifted to the left ear. It would mean that L1 is better inhibited in the left ear and L2 in the right ear when either language is attended to in the other ear. On these accounts, there may be a mechanism of *asymmetrical language control* subserved by each hemisphere for each language not in use at the moment. Due to the scarcity of research on the processing (i.e., inhibition) of and ear advantage for inhibition of *unattended* language in the DL task, because the focus is usually placed on the processing of the *attended* stimuli or language, these discussions remain to be speculative. Moreover, as a significant relationship between predictability, unattended language, and WMC was not found, it is not clear from the current results whether these different ear behaviours are due to the different roles subserved by the contralateral hemisphere (e.g., Abutalebi et al., 2000, 2007; Crinion et al., 2006; Kane & Engle, 2002).

Unexpectedly, WMC was found to favour to work for processing predictable language switches than for, more challenging, unpredictable language switches. There may be a strong relationship between WMC and processing of stimuli whose targets are systematically presented. It was also found that the earlier bilinguals start learning L2, the better they are able to deal with unpredictable language switches. This marginally significant interaction ($p = .0483$) between predictability

and AoA needs to be investigated further with participants with much earlier onset of bilingualism.

The BDL task with unpredictable and predictable switches of attended languages has shown that auditory attentional control in bilingual speech comprehension does not benefit from predictability of language switches as much as expected, although it seems to be differently beneficial for each ear. More research is required to investigate the effect of predictability of language switches on bilingual speech comprehension in each ear, how late or early the effect appears, and relationships between the benefit of predictable language switches and cognitive and experiential factors.

CHAPTER 8: GENERAL DISCUSSION

8.1 Motivation of the dissertation

In this dissertation, I conducted seven experiments to investigate the cognitive mechanism of bilingual speech comprehension at the passage level. Bilingual speech comprehension was considered as a cognitive process that entails continuous maintenance of attention to one of the languages and suppression of interference from another language. The seven experiments explored components of bilingual listening comprehension that are semantic relatedness, unattended language, ear preference, auditory attentional control, executive control, voluntary note-taking, and language switching, among others, to obtain answers to the pivotal question: How are bilinguals capable of maintaining listening comprehension in each of their languages?

This chapter gives a summary of the results and conclusions of each experiment, discusses the limitations of the bilingual dichotic listening paradigm, but also presents potential experimental manipulations and interdisciplinary approaches that can be integrated with this paradigm for future research. A summary table of effects across the seven experiments is shown in Table 8.1 with only significant and marginal results.

8.2 Summary of the experiments

I developed the bilingual dichotic listening (BDL) task based on the traditional dichotic listening task with meaningful passages in the bilinguals' two languages as a new experimental paradigm and utilised the simultaneity of stimulus presentation in the DL task to investigate the features of bilingual speech comprehension mentioned above. The DL paradigm has been employed in studies of attention (e.g., Cherry, 1953), hemispheric specialisation for language (e.g., Obrzut et al., 2001;

Table 8.1. *Generalised Linear Mixed Models Summary for All Experiments*

Experiment	Effect	<i>p</i>
1 (Preferred ear used without note-taking)	(Intercept) ^a	0.0001***
	Semantic relatedness (unrelated)	0.0161*
	Attended language (Japanese)	0.0001***
	Unattended language (Japanese)	0.0481*
	WMC	0.0057**
	L2 proficiency (residual)	0.0256*
	Exposure (speaking in L2)	0.0154*
	Exposure (speaking in L1)	0.0313*
2 (Non-preferred ear used without note-taking)	(Intercept) ^b	0.0001***
	Attended language (Japanese)	0.0001***
	Semantic relatedness* Unattended language	0.0120*
	Semantic relatedness* Attended language* Unattended language	0.0140*
	WMC	0.0498*
3 (Ear switching without note-taking)	(Intercept) ^c	0.0001***
	Attended channel (right)	0.0001***
	Attended language (Japanese)	0.0001***
	Unattended language (Japanese)	0.0234*
	WMC	0.0966(.)
	L2 proficiency	0.0198*

Shankweiler, 1966), auditory laterality (e.g., Hugdahl, 1995), and executive control (e.g., Colflesh & Conway, 2007; Conway et al., 2001), both in healthy individuals and patients with brain lesion. It has been recently adopted for studies on bilinguals to explore bilingual advantages in executive control (e.g., Filippi et al., 2012; Soveri et al., 2011). I decided to make use of the DL paradigm as it can give direct and abrupt interference that resembles the situation where bilingual listeners comprehend

Table 8.1. *Generalised Linear Mixed Models Summary for All Experiments (Continued)*

Experiment	Effect	<i>p</i>
4 (Preferred ear used with note-taking)	(Intercept) ^d	0.0001***
	Semantic relatedness (unrelated)	0.0075**
	Attended language (Japanese)	0.0001***
	WMC	0.0376*
	L2 proficiency (residual)	0.0488*
5 (Non-preferred ear used with note-taking)	(Intercept) ^e	0.9310 (ns)
	Semantic relatedness (unrelated)	0.0806(.)
	Attended language (Japanese)	0.0001***
	L2 proficiency	0.0040**
	Exposure (reading in L1)	0.0142*
	Exposure (writing in L1)	0.0101*
6 (Ear switching without note-taking)	(Intercept) ^f	0.0128*
	Attended channel (right)	0.0004***
	Attended language (Japanese)	0.0001***
	Unattended language (Japanese)	0.0319*
	Attended channel*Attended language	0.0001***
	Attended channel*Unattended language	0.0065**

one of their languages while coping with interference from another language in their mind. I considered that the DL paradigm could shed light on the cognitive mechanism of bilingual speech comprehension. Individual differences factors such as L2 proficiency, WMC, age of L2 acquisition (AoA), length of L2 learning (LoL), and exposures to each language (Exposure) were also examined in all seven experiments as explanatory factors for resolution of the cognitive and linguistic conflicts that arise in bilingual speech comprehension.

Table 8.1. *Generalised Linear Mixed Models Summary for All Experiments (Continued)*

Experiment	Effect	<i>p</i>
6 (Ear switching without note-taking) (Continued)	(Intercept) ^f	0.0128*
	WMC	0.0142*
	L2 proficiency (residual)	0.0001***
	Exposure (reading in L1)	0.0001***
	Exposure (writing in L1)	0.0362*
7 (Predictable language switching)	(Intercept) ^g	0.0001***
	Attended channel (right)	0.0001***
	Attended language (Japanese)	0.0001***
	Attended channel*Attended language	0.0028**
	Attended channel*Unattended language	0.0158*
	Attended channel*Attended language*Unattended language	0.0002***
	WMC	0.0001***
	L2 proficiency	0.0082**
	Exposure (listening in L2)	0.0215*
	Attended channel*WMC	0.0284*
	Attended channel*L2 proficiency	0.0477*

^a Model assumes baseline is a pair of semantically related passages, with English as the attended language and English as the unattended language.

^b Model assumes baseline is a pair of semantically related passages, with English as the attended language and English as the unattended language.

^c Model assumes baseline is a pair of semantically related passages, with left ear as the attended channel, with English as the attended language and English as the unattended language.

^d Model assumes baseline is a pair of semantically related passages, with English as the attended language and English as the unattended language.

^e Model assumes baseline is a pair of semantically related passages, with English as the attended language and English as the unattended language.

^f Model assumes baseline is a pair of semantically related passages, with left ear as the attended channel, with English as the attended language and English as the unattended language.

^f Model assumes baseline is a pair of semantically related passages, with left ear as the attended channel, with English as the attended language and English as the unattended language.

^g Model assumes baseline is a pair of semantically related passages, with English as the attended language presented to the left ear and English as the unattended language to the right ear.

(.)*p* < .10, **p* < .05, ***p* < .01, ****p* < .0001

Experiments 1 and 2 & Comparison between Experiments 1 and 2

Experiments 1 and 2 involved the use of the BDL task with pairs of passages that were different in semantic relatedness (i.e., related or unrelated) and languages the passages were heard in (i.e., L1 or L2). The attended language was randomly presented to the participants' preferred ear (Experiment 1) or non-preferred ear (Experiment 2), either left or right, and the unattended language randomly to the other ear. Experiment 1 attempted to extend the findings of previous studies for dichotic listening with the same language presented to each ear to bilingual dichotic listening. The previous monolingual studies found that semantically related information in the unattended ear is more disruptive of processing and memory for information in the attended ear than is semantically unrelated information (e.g., Beaman, 2004; Conway et al., 2001; Colflesh & Conway, 2007; Sörqvist et al., 2008). The question was whether the degree of interference from semantically related and unrelated information would be different when it is heard in the same language as the attended language compared to when it is heard in another language.

As predicted, the semantically related passages were more interfering with comprehension of the attended passage than the semantically unrelated passages, remarkably regardless of language for comprehension and language to be suppressed. The result is also noticeable because it extends the previous findings at the syllable, word, and sentence levels to the passage level.

The BDL paradigm has uncovered a different effect of the dominant language on the processing of the target language that is incompatible with previous findings and theories of bilingual language control (e.g., Blumenfeld & Marian, 2007; Green, 1998; Weber & Cutler, 2004). In the previous studies with the visual-world paradigm where both the target and distractor were visual, the distractor in L1 was found to interfere with the target in L2, whereas in the BDL task where both the target and distractor were auditory, the distractor in L1 was found to in fact facilitate comprehension of the target language, whether it was semantically related or unrelated and L1 or L2. As different modalities (i.e., visual or auditory) have

different degrees of interference on the target stimulus (e.g., Latorella, 1998; Rees et al., 2001; Stanton et al., 1992), the characteristics of interference caused by L1 need to be considered differently between these two experimental paradigms. It has to be also noted that a reform of the theory of inhibitory control may be required as it is mostly based on the studies of speech production (e.g., word production) and has been presumably overgeneralised to inhibitory control in speech comprehension, although more research undoubtedly needs to be conducted on inhibitory control solely in speech comprehension. A revised theory of inhibitory control should conform to inhibitory control required in speech comprehension among bilinguals.

Predictors for resolution of the cognitive and linguistic conflicts occurring in the BDL stimuli were, as expected, high L2 proficiency and WMC, with L2 proficiency selectively related to comprehension of L2, and with WMC related to comprehension of both languages (e.g., Festman et al., 2010). The AoA, LoL, and amount of exposure to each language that have been found to influence the bilingual brain organisation (e.g., Malt & Sloman, 2003; Wartenburger et al., 2003; Weber-Fox & Neville, 1996; Whitford & Titone, 2012) did not serve as good predictors of executive control in speech comprehension among the current participants.

Bilingual language lateralisation (i.e., ear preference) was examined in a cross-experimental analysis between Experiment 1 where preferred ear was used and Experiment 2 where non-preferred ear was used. Comprehension was better through the favourable ear-to-hemisphere route (i.e., preferred ear) than through the unfavourable route, whether it was left or right. Between the left and right ears, comprehension in the left ear as the preferred ear was better than that in the right ear that was chosen by most of the participants as their preferred ear. No differences were found in the experiential factors between those who chose their left ear as their preferred ear and those who chose their right ear as their preferred ear. Although not significant, a tendency of higher L2 proficiency and WMC in those who preferred to use their left ear may have altered their lateralisation patterns from left to right (e.g., Hernandez et al., 2000; Klein et al., 1999).

The cross-experimental analyses have demonstrated that most of the current participants who were late bilinguals are left-lateralised (78%), i.e., right-eared, and some are right-lateralised (22%), i.e., left-eared, for both of their languages, which furthers the previous findings at the word level (e.g., D'Anselmo et al., 2013; Green, 2003; Hull & Vaid, 2007; Morton et al., 1998; Ullman, 2001) to the passage level.

Experiment 3

Experiment 3 examined auditory attentional control in bilingual speech comprehension in the BDL task in which the stimuli were all semantically related pairs of passages and attention shifting was required. As has been observed in the traditional DL task (e.g., Beaman, 2004; Hugdahl et al., 2009; Sörqvist et al., 2008; Soveri et al., 2011), the right-ear advantage (REA) was confirmed, which means that bilingual listeners perform better in their right ear than in their left ear while switching ears, maintaining their attention to one language, and suppressing another in each ear, regardless of language in the attended and unattended channels. It was moderately shown that it is harder for the right ear to inhibit Japanese than English when attention has to be paid to Japanese, and either language seems to interrupt comprehension in the left ear.

The laterality index that is somewhat consistent with that found in previous studies (e.g., Hugdahl, 1995, 2003; Hugdahl & Andersson, 1986) would give moral support to the validity of the BDL task to investigate the degree of ear advantage among bilingual listeners. Comprehension of pairs of passages that had less semantic competition (compared to those used in Experiment 1) did not require WMC as much as expected, but required higher L2 proficiency for attentional control between semantically related passages in both languages and resolving within- and between-language competition in each ear.

Experiments 4 and 5 & Comparisons between Experiments 2 and 5, and between Experiments 4 and 5

In order to obtain a picture of more practical aspects of the cognitive mechanism of bilingual speech comprehension, the effect of note-taking was considered in a cross-experimental analysis between Experiment 1 where note-taking was prevented and Experiment 4 where note-taking was allowed in the BDL task. In both experiments, attention was directed to the preferred ear. Note-taking facilitated comprehension of attended language, inhibition of unattended language, and resolution of linguistic and semantic competition, all of which are accomplished by high L2 proficiency and WMC. The result confirms that these cognitive functions are fulfilled through the favourable ear-to-hemisphere route (i.e., preferred ear, whether left or right), and performances are enhanced by voluntary note-taking (e.g., Craik & Bialystok, 2006; Emmorey et al., 2008, Green, 1998).

The effect of note-taking was also examined in a cross-experimental analysis between Experiment 2 where note-taking was prevented and Experiment 5 where note-taking was allowed, in both of which non-preferred ear was used. Note-taking enhanced maintenance of attention to one language and suppression of another that were different in semantic relationships also in the non-preferred ear. The result confirms that WMC is required in the most disadvantaged condition where non-preferred ear has to be used and note-taking is prevented.

Language lateralisation was examined in a cross-experimental analysis between Experiment 4 where preferred ear was used and Experiment 5 where non-preferred ear was used, in both of which note-taking was allowed. Counterintuitively, comprehension was better in the non-preferred ear.

Comparisons between 1, 2, 4, and 5

A further cross-experimental analysis between Experiments 1, 2, 4, and 5 demonstrated that note-taking facilitates listening comprehension in general, but in

fact negatively hampers listening performance when attention is paid to the preferred ear.

Experiment 6 & Comparison between Experiments 3 and 6

The effect of note-taking was further examined on auditory attentional control in a cross-experimental analysis between Experiment 3 where note-taking was prevented and Experiment 6 where note-taking was allowed. As has been found in Experiment 3, the right-ear advantage was also found in Experiment 6, meaning that note-taking does not influence attentional control. Note-taking aided auditory attentional control and led to better comprehension. The laterality index in Experiment 6 was much smaller than that in Experiment 3, probably because performance in the left ear was somehow balanced out by voluntary note-taking. There were great demands on WMC when the external memory (i.e., note-taking) was not available, suggesting that note-taking may reduce the demands on WMC, whereas L2 proficiency was demanded regardless of the availability of the external memory.

Experiment 7 & Comparison between Experiments 6 and 7

The effect of predictability of language switching on auditory attentional control between channels and resolution of conflicts from the unattended language was examined in a cross-experimental analysis between Experiment 6 where the attended languages (i.e., L1 and L2) were randomly presented and Experiment 7 where the attended languages were systematically presented. In both experiments, the participants were allowed to take notes.

The effect of predictability of language switching was observed in each ear. Performance was better in the left ear when language switches were predictable than when they were unpredictable, and performance was better in the right ear when language switches were unpredictable than when they were predictable. These results are supported to some degree by neuroimaging evidence that the right hemisphere is

more involved when processing predictable switches (e.g., Kimberg et al., 2000; Swainson et al., 2003), where proactive control could be engaged (e.g., Braver, 2012; Miller & Cohen, 2001) and the left hemisphere is more involved when processing unpredictable switches (e.g., Erickson et al., 2005; Luks et al., 2002), where reactive control could be engaged (e.g., Braver, 2012; Jacoby et al., 1999; see also Morales et al., 2013). With regard to inhibition of unattended language, L1 was better inhibited in the left ear and L2 in the right ear regardless of attended language. Hence, a mechanism of asymmetrical language control is suggested, in which each hemisphere serves to inhibit each language. WMC was found to be more related to processing of predictable language switches than unpredictable language switches, implying a strong link between WMC and processing of favourable language switches.

8.3 Discussion of the bilingual dichotic listening paradigm

There are several limitations that need to be discussed with regard to the experimental paradigm, which, with proper amendments and approaches from other disciplines integrated with the BDL paradigm, could show more valid findings and insights into the cognitive mechanism of bilingual speech comprehension in the future research.

8.3.1 Bilingual participants

First and foremost, it is accepted that the results presented here would not generalise to the whole bilingual population since the current participants were all late bilinguals who started learning L2 much later than those in previous studies (e.g., Bialystok, 1999; Obler et al., 2007; Perani et al., 2003; Soveri et al., 2011). The later onset of bilingualism resulted in lower L2 proficiency and WMC, and less experienced in bilingual language behaviours (i.e., communicating with other bilinguals while switching between their languages when necessary), leading to

somewhat weak or even no relationships between the individual differences factors and speech comprehension assessed in the BDL task, and between the cognitive factors and experiential factors. The current participants may be childhood bilinguals (Hull & Vaid, 2007) with the onset age of L2 learning between 6 and 13 and intermediate level of L2 proficiency, but it is unquestionable that their L2 learning style, its quality, extensiveness, amounts of exposure to each of the two languages, and frequencies of switching between them, do vary individually and have influenced the current results.

It is difficult to control for all of these variables and it is not sensible to suppose that all bilinguals are equivalent in the degree of bilingualism. For example, there are in fact not only bilinguals who are more exposed to their L1 than L2, i.e., L1 dominant, but also those who are more exposed to their L2 than L1, i.e., L2 dominant. There is evidence that decreased exposure to a given language, whether it is L1 or L2, enhances controlled processing for that language (e.g., Abutalebi et al., 2007). Hence, considering these variations of bilingual characteristics (i.e., early or late bilinguals, proficient or less proficient bilinguals, formal or informal learning of L2, and more or less exposed to L2) will give a reliable picture of speech comprehension behaviours among bilinguals in general.

8.3.2 *Stimulus complexity in the BDL paradigm*

The fundamental concept of the BDL paradigm is that the auditory stimuli are presented in the bilinguals' two languages and their attention is directed to one of their ears while they have to overcome cognitive and linguistic conflicts coming from the other ear. Semantically related and unrelated pairs of passages were used in four experiments (i.e., Experiments 1, 2, 4, and 5) and only semantically related pairs of passages were used in three experiments (i.e., Experiments 3, 6, and 7). The passages consisted of natural sentences selected from news articles as the primary motivation was to investigate comprehension of natural speech that bilingual listeners would encounter in their everyday life.

Thus, the features of interference the bilingual participants had to overcome in the BDL task are restricted to semantic (i.e., semantically related and unrelated) and linguistic (i.e., interference from L2 on L1, and vice versa) in this dissertation. Comprehension invariably involves not only semantic, but also phonological, syntactic, and pragmatic features. These diverse linguistic features (Brown et al., 2000) and the physical characteristics of speech (e.g., speech rate, Shi & Farooq, 2012) place particular demands on the listener. As the mode of stimulus presentation or stimulus characteristics can modulate, for example, the degree of ear advantage (Westerhausen & Hugdahl, 2010), more cognitively demanding manipulations (e.g., syntactic, phonological, or stimuli at different speech rates or volumes) for the future BDL task could more clearly demonstrate cognitive features of bilingual speech comprehension in the everyday situation. Integrations of these characteristics of speech with the BDL paradigm are presented below.

A further experimental manipulation for the BDL task can be drawn from studies in which the stimulus sentences are different in their syntactic complexity (e.g., Makuuchi et al., 2009; Newman et al., 2009; Prat et al., 2007). For example, Prat et al. (2007) manipulated the syntactic complexity (two-clause active-conjoined and object- relative sentences) and lexical frequency (high and low noun frequency), e.g., Active-conjoined (simple): *The writer attacked the king and admitted the mistake at the meeting*; Object-relative (complex): *The writer that the king attacked admitted the mistake at the meeting*. The task was to read the sentences and answer true-false questions. fMRI revealed that participants with high WMC were found to be more efficient than those with low WMC in their reading performance, and better able to adapt to the increasing lexical and syntactic demands.

Using simple sentences with different syntactic structures, i.e., canonical or non-canonical, Filippi et al. (2012) have shown a bilingual advantage in inhibiting language interference in sentence comprehension in the DL paradigm. Their study could be extended with the BDL paradigm taking syntactic complexity in passages into consideration in order to explore which ear (i.e., preferred or non-preferred ear, or even both ears with the same participants) better resolves syntactic interference

and whether there would be an REA for processing passages with different degrees of syntactic complexity. The former question can be investigated in the same way as Experiments 1 and 2. Instead of semantic relatedness, syntactic complexity is included as a fixed effect, producing a 2 (syntactic complexity (simple, complex) \times 2 (attended language (English, Japanese) \times 2 (unattended language (English, Japanese) repeated measures design. The latter question can be investigated in the similar way to Experiment 3 by adding an ear-switching paradigm, producing a 2 (ear (left, right) \times 2 (syntactic complexity (simple, complex) \times 2 (attended language (English, Japanese) \times 2 (unattended language (English, Japanese) repeated measures design. L2 syntactic complexity analyser (Lu, 2010) can be employed to calculate ratios of syntactic complexity between two passages with up to 1,000 words each (available at <http://aihaiyang.com/synlex/syntactic/>). This analyser counts the frequency of 9 grammatical structures in the text and computes 14 indices of syntactic complexity of the text.

Cognitive demands on speech comprehension could be further increased with variations of speed (e.g., Gordon et al., 2009) or interaural intensity (Hugdahl et al., 2009) of speech stimuli to investigate the amount of cognitive control necessary to resolve the interference. It has been found in the field of cognitive ageing that older adults are more adversely affected by rapid speech (even spoken material in everyday situations) than are younger adults owing to cognitive slowing (Cerella, 1990; Salthouse, 1996). L2 listeners are also affected by the speed of speech when listening to L2 and the inability of working memory to process all the information within the time limitations (Flowerdew & Miller, 2005, p. 27). Considering differences in interaural speed in the BDL task, it would be possible to explore the cognitive mechanism of resolution of interference from an unattended passage at a different speech rate and in the same or different language as no two people speak at the same rate in an everyday situation (e.g., Littlefield et al., 2001; Miller et al., 1984) and bilingual listeners need to adapt themselves to these variations which influence speech recognition (e.g., Miller et al., 1984).

Hugdahl et al. (2008) have found that in the non-forced condition of their DL task gradual increases of the right ear stimulus intensity caused a corresponding right-ear advantage (REA) and in the similar vein gradual increases of the left ear stimulus intensity caused a corresponding left-ear advantage (LEA). In the forced-attention DL paradigm, Tallus et al. (2007) have demonstrated that it is difficult to focus attention to the left ear when the left ear stimulus is weaker, indicating no LEA, whereas when the right ear stimulus is weaker, it is significantly easier to focus attention to the right ear, indicating an REA. As speakers do not always speak at the same volume (Opperman & Hancke, 2012), the BDL stimuli at different intensities might be able to investigate whether stimulus intensity influences the degree of ear advantage for processing one language and suppressing another.

8.3.3 *Multi-talker environment in the BDL paradigm*

It has been explicitly demonstrated that bilingual listeners are significantly worse than monolingual peers at comprehension, for example, when the target is embedded in background noise (e.g., García Lecumberri & Cooke, 2006; García Lecumberri et al., 2010; Mayo et al., 1997; Rogers et al., 2006; Van Engen, 2010). The noise included in these studies is called a multi-talker babble and this babble consists of two or more speakers speaking at the same time as the target speaker. Investigations on speech perception under these adverse conditions have aimed to understand the problems faced by native listeners as well as L2 learners in everyday listening situations (García Lecumberri et al., 2010).

Van Engen and Bradlow (2007) demonstrated that native English listeners, for whom Mandarin is a foreign language, are more adversely affected by English babble than Mandarin babble, suggesting that L1 has a greater influence on sentence intelligibility in noise than a foreign language. They also stated that linguistic interference plays a role in the perception of speech in noise as they found that native English listeners perform better on a sentence intelligibility task in the presence of Mandarin two-talker babble than in English two-talker babble. The target sentences

were meaningful sentences (e.g., *The children dropped the bag*). Semantically anomalous sentences were used as the noise sentences (e.g., *My puppy may stress their fundamental gallon*) to eliminate the possibility that participants might extract an entire meaningful sentence not from the target speaker but from the babble.

Van Engen (2010) replicated the earlier study but recruited both native speakers of English and Mandarin speakers of English as L2 to address the role of listeners' experience with both the target and noise languages by examining the effect of noise of both L1 and L2 on sentence recognition in L2. The target language was always English. It was found that English babble was more interfering than Mandarin babble for both groups of listeners. The effect of Mandarin babble was positive for native English speakers, that is their performance was better when they heard Mandarin babble than English babble. For native Mandarin listeners, their L1 was more disruptive than their L2 and the difference in their performance between when they heard L1 babble and when they heard L2 babble was larger than for native English listeners. Van Engen (2010) concluded that both the similarity between the target and noise (i.e., English target and English babble) and the language experience of the listeners (i.e., experience in learning L2) contribute to the amount of interference listeners experience when listening to speech in the presence of speech noise.

It is conceivable that a babble in a foreign, never learned, language was less interfering than one's L1 as discovered by Cherry (1953) in the DL task that listeners seldom noticed when the message in the unattended channel was in a foreign language, although the unattended message is not entirely unprocessed (e.g., Alho et al., 2003; Lachter et al., 2004; Moray, 1959). It is implausible, however, to argue that it was more difficult for native Mandarin listeners than native English listeners to filter out Mandarin babble by comparing the effect from one's foreign language with the effect from one's first language. In my BDL experiments (Experiments 1 and 6), the unattended L1 has been in fact found to enhance comprehension of the attended language, which is in opposition to their results. Furthermore, the target and babble stimuli in these studies were all semantically incongruent (i.e., semantically *unrelated*), and the babble stimuli were semantically irregular (despite the fact they

used the semantically anomalous babble to eliminate the chance of recall from the babble). Hence, there may also have been an influence from this semantic incongruity on the results, as has been found in my experiments (Experiments 1 and 4) that semantically *unrelated* pairs of passages are easier to suppress, whether the attended and unattended languages are L1 or L2, than semantically *related* passages. The semantically anomalous babble in Mandarin may have drawn more attention of Mandarin native listeners, thereby leading to a larger difference in performance between when they heard English babble and when they heard Mandarin babble.

Nevertheless, it would be interesting to integrate the multi-talker paradigm into the BDL paradigm to explore the cognitive mechanism of bilingual speech comprehension in a situation which seems closer to the everyday listening situation than the original BDL situation. To make the most of the multi-talker paradigm and constrict the interfering features of the babble to semantic relatedness and unattended language, a hybrid version of the cocktail-party task that produces within-ear interference between target (T) and masker (M) 1 and across-ear interference between T and M2 (e.g., Brungart & Simpson, 2002, 2004) could be employed to examine the bilingual listener's ability to segregate competing talkers in the target ear even when they are presented in their two languages. A *multi-talker BDL task* could create a cognitively demanding situation, as encouraged by Mercier et al. (2013), to examine the bilinguals' inhibitory and attentional mechanisms to cope with the demand of managing their two languages in speech comprehension and to investigate whether within-ear interference would be stronger than between-ear interference or vice versa, in both of which the target and maskers are heard in the same or different languages and different in semantic complexity.

8.3.4 Online measures of speech comprehension

In the BDL paradigm, no online measures such as reaction times to investigate the cognitive mechanism and inhibitory control in bilingual speech comprehension were

available. One behavioural online measure of listening comprehension which could be applied to the BDL paradigm is the self-paced listening task (e.g., Ferreira et al., 1996; Heredia & Vaid, 2002; Waters et al., 2002), which provides a segment-by-segment measure of processing time (Felser et al., 2003). The stimuli are presented in a segment-by-segment fashion, for example, *The doctor recognised / the nurse of the pupils / who / was / feeling very tired*. The focus of assessment in the self-paced listening task is the reaction times between the onset of each segment and a button press to proceed to the next segment and accuracy rates in comprehension questions at the end of either each sentence or at the end of a proportion of the sentences. In this example, the factor that can influence the reaction times is the necessity to disambiguate the auxiliary, e.g., *was*, in the example above.

In the similar vein, a *self-paced BDL task* could be developed and employed to examine the time spent on listening to each segment and compare, for example, durations between when the passages are semantically related and when they are semantically unrelated, durations between when the attended language is English and when it is Japanese, and durations between when the unattended language is English and when it is Japanese. Although it is not in accord with the original concept of the BDL task, it might be necessary to reduce the size of stimuli from passage to sentence so as to inspect more precisely how interference from the other ear influences the processing time of the attended sentence and comprehension accuracy.

Neurocognitive online measures such as MEG, PET, and fMRI (e.g., Hugdahl et al., 2009) may lend a supplementary hand to uncovering of the cognitive mechanism of auditory attentional control in comprehension of passages among bilinguals in the BDL task. In the recent review on the neuronal basis of speech comprehension, Specht (2013) states that in relation to the dichotic listening task, the corpus callosum (the nervous fibres connecting both hemispheres (Jäncke & Steinmetz, 2003, p. 204)) is an important factor and inter-individual variations in corpus-callosum size are related to the strength of the REA (e.g., Westerhausen et al., 2010; Westerhausen & Hugdahl, 2008; Westerhausen et al., 2011). He also maintains the importance of considering the individual structural variability, not only within the corpus callosum,

but also individual variability in other language related structures such as the asymmetrical depth of the superior temporal sulcus (STS) between hemispheres (e.g., Im et al., 2010), an important structure for speech comprehension, and the configuration of the different segments of the arcuate fasciculus which connects Broca's area with Wernicke's area. Although behavioural consequences of the asymmetry of the depth of the STS have not been investigated in detail yet (Specht, 2013), a higher symmetry in the arcuate fasciculus between hemispheres has been found to be related to a better performance in the semantic association task (e.g., Catani et al., 2007).

It would be informative to investigate how these brain structures react to each of eight pairs of passages which have different semantic and linguistic relationships (i.e., semantically related English-English, semantically related English-Japanese, semantically related Japanese-English, and semantically related Japanese-Japanese. Another four semantically unrelated pairs of passages in the same four language conditions) through both favourable and unfavourable ear-to-hemisphere routes, and to the demand to shift between ears (i.e., four pairs of passages presented to the right ear: Right-English-English, Right-English-Japanese, Right-Japanese-English, Right-Japanese-Japanese). Another four pairs of passages presented to the left ear in the same four language conditions), and whether the availability of note-taking and predictability of language switches would also affect brain activation in these conditions. It is predicted that executive control areas such as the DLPFC, ACC, BG, SPL, and left caudate (e.g., Abutalebi et al., 2007; Crinion et al., 2006; Hernandez, 2009; Holtzheimer et al., 2005; Rodriguez-Fornells et al., 2006; Van Hueven et al., 2008) would show activation when resolving semantic and linguistic conflicts. The mechanism of asymmetrical language control (see 6.15) could be also examined by comparing brain activation between when the unattended language is English and when it is Japanese.

Lastly, the concept of dual mechanisms of cognitive control in bilinguals has to be mentioned as it suggests that the superior performance of bilinguals in executive control tasks may be better explained by considering the dynamic combination of the

two types of executive control mechanisms (i.e., proactive/monitoring control and reactive/inhibition control (e.g., Bialystok et al., 2012; Costa et al., 2009; Colzato et al., 2008; Morales et al., 2013)). This concept would better help understand the cognitive mechanism of bilingual speech comprehension along with the amendments and approaches from other disciplines integrated with the BDL paradigm discussed above.

8.4 Final conclusion

This dissertation endeavoured to explore the cognitive mechanism of bilingual speech comprehension of passages in a series of experiments in the bilingual dichotic listening paradigm. The results have shown some possibility that the BDL task with meaningful passages can be used to examine how bilingual listeners sustain their attention to one of their languages while suppressing another language which is activated simultaneously to some extent in their mind. I first showed that semantically related passages interfere more with comprehension than semantically unrelated passages whether the attended and unattended languages are heard in the same or different languages. I found that the dominant language in fact has a facilitatory role in maintenance of attention to both languages in the BDL task where both the target and distractor are auditory. I then demonstrated that there is a favourable ear-to-hemisphere route for resolving semantic and linguistic competition regardless of language to comprehend and language to inhibit. I further demonstrated a right-ear advantage for bilingual speech comprehension. Subsequently, I found that note-taking facilitates comprehension in general, but hinders comprehension in concert with preferred ear. Lastly, I found that predictability of language switches does not enhance overall comprehension, but predictable language switches facilitate comprehension in the left ear and unpredictable language switches facilitate comprehension in the right ear. Despite these findings, there is still a long way until definite answers can be found to the question of how bilinguals are capable of maintaining listening comprehension in each of their languages.

In general, high L2 proficiency and WMC play crucial roles in comprehending one language while inhibiting another language. Overall, L2 proficiency is more related to comprehension of L2 than that of L1. WMC appears to function better when there is strong semantic competition, through favourable ear-to-hemisphere route, when note-taking is prevented, and for processing predictable language switches.

Discussions on implications of these findings with regard to the cognitive mechanism of bilingual speech comprehension are presented. This dissertation ends with examples of how the bilingual dichotic listening paradigm can be applied to answer a variety of research questions related to bilingual speech comprehension by refining and integrating it with approaches from other disciplines.

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- Miura, T., Pickering, M. J., Logie, R. H., & Sorace, A. (2011, August). *The role of working memory capacity in the bilingual dichotic listening task*. Paper presented at the 5th International Conference on Memory, University of York, England, UK.
- Miura, T., Pickering, M. J., Logie, R. H., & Sorace, A. (2011, August). *Auditory attentional control in bilingual speech comprehension: Explorations in the bilingual dichotic listening paradigm*. Paper presented at the 37th Annual Convention of Japan Society of English Language Education, Yamagata University, Yamagata, Japan.

Appendices

A.1.: Earedness questionnaire

		Left (-1)	Mixed (0)	Right (+1)
1	Which ear do you use when you use your mobile phone?			
2	Which ear do you use when you use your mobile phone in English?			
3	Which ear do you use when you use your mobile phone in Japanese?			
	Total			
	Earedness Judgement (positive = Right, negative = Left)			

A.2: English proficiency test

The actual proficiency test was given on one A4 sheet, 15 items on one side and another 15 items on the other side. The size of the font was 10.5 to save space and paper.

1. ‘talkative.’ の反対の意味の単語を選びなさい。

audible loud quiet mild

2. 下線部に‘o’ で始まるINSIDEの反意語を書きなさい。

On a sunny day I usually go _____ to get some fresh air. Who wants to stay INSIDE anyway?

3. 下線部に最も当てはまる単語を以下の4つの単語の中から選びなさい。

It may be possible to _____ damages against a local authority for not taking care of the roads well enough.

claim ask sue bet

4. ‘sick’と同様の意味で‘i’ から始まる単語を書きなさい。

5. 下線部に最も当てはまる単語を以下の4つの単語の中から選びなさい。

The _____ and butter of my life? I don’t know ...The family? And my work. Making a good living, I suppose.

oil salt bread cheese

6. Teaching と同じ意味の単語を以下の4つの単語の中から選びなさい。

There are a number of books and videos on the market, but it’s still hard to learn ‘tai chi’ without personal TEACHING.

selection reading adaptation instruction

7. 以下の2つの文を補う共通した単語を書きなさい。

It’s raining cats and ...s. Treat somebody like a _____

8. 'known'の反意語を下線部に書きなさい。

The beach was _____ to us, because we lived so far away from it.

9. 下線部に最も当てはまる単語を以下の4つの単語の中から選びなさい。

The armed thief shot the sheriff, and injured the _____ standing next to him.
power shelter deputy fortune

10. WISHと同じ意味の単語を以下の4つの単語の中から選びなさい。

It has been my most sincere WISH for some time now.
fault desire request purpose

11. 下線部に当てはまる単語を書きなさい。

Good-better-best _____-worse-worst

12. 'a'で始まる下線部に当てはまる単語を書きなさい。

He was badly injured and they took him to hospital in an _____.

13. 'any'を付けられない単語を選びなさい。

how one way why where

14. 下線部の単語の欠けている部分を補いなさい。

My employ_____ gave me a bonus for working overtime.

15. 下線部に最も当てはまる単語を以下の4つの単語の中から選びなさい。

I can't _____ with your offer. Anyone would take a pizza instead of a soup mix.
oppose struggle examine compete

16. 下線部に最も当てはまる単語を以下の4つの単語の中から選びなさい。

Don't wait any longer, you have to strike while the _____ is hot. iron gold steel metal

17. 下線部に最も当てはまる単語を以下の4つの単語の中から選びなさい。

The _____ of this factory is increasing. title product output aim

18. ‘c’で始まる下線部に当てはまる単語を書きなさい。

The _____ of her eyes is brown.

19. 下線部の単語の欠けている部分を補いなさい。

The future develop_____ of the European Union depends on what the member states want out of Europe.

20. ‘motion’と同じ意味の単語を選びなさい。

movement watching reacting converting

21. ‘v’で始まる下線部に当てはまる単語を書きなさい。

He is a pathological killer. His first _____ was 30-year-old Tamara Lind, a former girlfriend.

22. ‘consider’と同じ意味の単語を選びなさい。

relate regard expect promise

23. 下線部の単語の欠けている部分を補いなさい。

My latest novel was _____jected by the first three publishers, but with the fourth one I got lucky!

24. 下線部の単語の欠けている部分を補いなさい。

I will try to _____press my feelings more openly, but I’m not sure I can.

25. 以下の2つの文の...に当てはまる、共通した単語を4つの中から選びなさい。

We built a sandcastle. It ... when the waves came.

Our plans ..., when the time allowed for completion was changed.

declined ruined collapsed devastated

26. 以下の疑問文の答えとなる‘f’で始まる単語を書きなさい。

What is usually out around a garden to separate one house from another? _____

27. 'unc' で始まる下線部に当てはまる単語を書きなさい。

The seats were rather _____, and it was not easy to remain sitting down all the time.

28. 下線部の単語の欠けている部分を補いなさい。

The Guggenheim Museum is being hailed as the greatest architectural master _____ of this century.

29. DISCOURAGE の反意語を下線部に書きなさい。

But the state should go further to DISCOURAGE impressionable children from smoking, says political activist Steven Brown.

30. LOUNGE と同じ意味の表現を選びなさい。

The hotel has a small pleasant LOUNGE and bar, two terraces (one on the roof), a solarium (payable locally) and a sauna (free).

restaurant discotheque hallway public room

A.3: Latin square design of passage presentation (Experiments 1, 2, 4, and 5)

Semantically Related							
Subjects	Attended	Unattended	Attended	Unattended	Attended	Unattended	
	English	English	English	Japanese	Japanese	English	Japanese
1	A1	A2	B1	B2	C1	C2	D1
	A3	A4	B3	B4	C3	C4	D3
2	D1	D2	A1	A2	B1	B2	C1
	D3	D4	A3	A4	B3	B4	C3
3	C1	C2	D1	D2	A1	A2	B1
	C3	C4	D3	D4	A3	A4	B3
4	B1	B2	C1	C2	D1	D2	A1
	B3	B4	C3	C4	D3	D4	A3

Semantically Unrelated							
Subjects	Attended	Unattended	Attended	Unattended	Attended	Unattended	
	English	English	English	Japanese	Japanese	English	Japanese
1	E1	E2	F1	F2	G1	G2	H1
	E3	E4	F3	F4	G3	G4	H3
2	H1	H2	E1	E2	F1	F2	G1
	H3	H4	E3	E4	F3	F4	G3
3	G1	G2	H1	H2	E1	E2	F1
	G3	G4	H3	H4	E3	E4	F3
4	F1	F2	G1	G2	H1	H2	E1
	F3	F4	G3	G4	H3	H4	E3

A.4: Passages and sentence-completion items in the BDL task (Experiments 1, 2, 4, and 5)

The pairs of passages presented below were used in Experiment 1 where participants used their preferred ear, in Experiment 2 where participants used their non-preferred ear, in both of which note-taking was not allowed, in Experiment 4 where participants used their preferred ear and in Experiment 5 where participants used their non-preferred ear, in both of which note-taking was encouraged. The passage participants had to comprehend is labelled as attended passage (A1, A3, B1, B3, C1, C3, D1, D3, E1, E3, F1, F3, G1, G3, H1, and H3) and the passage they had to suppress as unattended passage (A2, A4, B2, B4, C2, C4, D2, D4, E2, E4, F2, F4, G2, G4, H2, and H4). A, B, C, and D represent that the passages are semantically related, and E, F, G, and H represent that the passages are semantically unrelated. Odd numbers are for attended passages and even number for unattended passages. Sentence-completion items follow each attended passage, then the unattended passage. These sixteen pairs of passages were counterbalanced in a Latin square design (see Appendix A.3) while maintaining their semantic relationships, but changing their language sets. Each passage, whether attended or unattended, was presented in English to one participant and in Japanese to another participant as shown in Appendix A.3. Hence, attended and unattended passages are presented in both English and Japanese, except for a pair of passages for a practice session where the attended passage is in English and unattended passage in Japanese. Semantic relatedness of each pair of passages is indicated beside each passage pair title (e.g., A1 and A2 - LSA: 0.74).

Practice session: Semantically unrelated English-Japanese passages - LSA: 0.31

Attended passage in English:

Maybe you know that an adult in the UK will probably need about 1,700 kilocalories a day on average; someone in Antarctica will need about 3,500 - just over double! It's perhaps the climate change research that is the most crucial field of study. Within this general field, surveying changes in the volume and stability of the ice-cap is vital, since these may have profound effects on world sea levels and on ocean currents. A second important area is monitoring the size of the hole in the ozone layer above Antarctica, since this is an indicator of global ultra-violet radiation levels. Thirdly, bubbles in the ice-sheet itself provide an index of pollution because frozen inside them are samples of previous atmospheres over the past 500,000 years. There are an increasing number of opportunities for young people to work for a period in Antarctica.

Sentence-completion items:

1. Average daily requirement for an adult in Antarctica is approximately kilocalories.
2. They measure changes in the ice-cap because of effects on sea levels and
3. The size of the hole in the layer indicates the level of global ultra-violet radiation.
4. Air from bubbles in ice is analysed to measure
5. There are many job vacancies for people in Antarctica.

Unattended passage in Japanese:

木は、風を防ぐのに役立ちます。高い建物の地面近くで風がより強くなる理由は、風がより強くなるのに応じて、より速くなるからです。木がある時、それは起こりません。木は、風を浸透させ、力をかなり減少させます。市街地での別の問題は、車からの騒音が高層ビルによって強められることです。また、効果は期待するほど

大きくはありませんが、木は周囲の雑音を減少させるのに役立ちます。特に周波数の低い騒音は、まるでそこに存在しないかのように、ただ木を通って行きます。木は都市近郊の気候をかなり改善できますが、多くの場所を取ってしまいます。高層建築が密集している狭い通り、いわゆる通りの峡谷があれば、出来ることはほとんどありません。木が成長するためには水が必要です。また、木の成長には日光が必要です。そして、木を置く場所も必要です。

(Trees can also help break the force of winds. The reason that high buildings make it windier at ground level is that, as the wind goes higher and higher, it goes faster and faster. That doesn't happen when you have trees. Trees filter the wind and considerably reduce it, preventing those very large strong gusts that you so often find around tall buildings. Another problem in built-up areas is that traffic noise is intensified by tall buildings. Trees can also help reduce the amount of noise in the surroundings, although the effect is not as large as people like to think. Low-frequency noise, in particular, just goes through the trees as though they aren't there. Although trees can significantly improve the local climate, they do however take up a lot of space. There is not a great deal you can do if you have what we call a street canyon - a whole set of high-rises enclosed in a narrow street. Trees need water to grow. They also need some sunlight to grow and you need room to put them.)

Eight semantically related pairs of passages (A1 & A2, A3 & A4, B1 & B2, B3 & B4, C1 & C2, C3 & C4, D1 & D2, and D3 & D4) (see Appendix A.3)

1. A1 and A2 - LSA: 0.74

Attended passage A1 in English:

Developmental psychologists are trying to understand lying through behaviour. Neuroscientists are tracking which regions of the brain are activated when we spin lies. Their results could shed light on issues from why a tween lies to your face about breaking a vase to whether young children can be trusted to give eye-witness testimony in court. One intriguing new study suggests that lying may spring from a completely different part of the brain in children compared with adults. What has become clear from studies including the work of Kang Lee, a professor at the University of Toronto and director of the Institute of Child Study, is that lying is a sign of normal maturation. Parents and teachers who catch their children lying "should not be alarmed - and their children are not going to turn out to be pathological liars," says Dr. Lee, who has spent the last 15 years studying how lying changes as kids get older, why some people lie more than others as well as which factors can reduce lying. "The fact that their children tell lies is a sign that they have reached a new developmental milestone."

Sentence-completion items:

1. Developmental psychologists want to understand the mechanism of lying through
2. Children lie when they break a
3. Lying indicates a maturation of children.
4. Teachers don't need to be when they see their children lying.
5. Children who tell a lie have reached a new stage.

Attended passage A1 in Japanese:

発達心理学者は行動を通して嘘を理解しようとしています。脳科学者は、作り話をするとき脳の中のどの部分が活性化しているかを追跡しています。彼等の研究結果が、もしかしたら、幼い子供が花瓶を割ったことの嘘をつくのは何故か、という問題から、十代の子供の目撃者としての法廷での証言が信頼出来るかどうか、という問題に渡るまで答えを出してくれるかもしれません。とても興味深い最新の研究によって、子供が嘘をつくときの脳の部位と大人が嘘をつくときの脳の部位が異なることが分かりました。トロント大学の教授で、児童研究所の所長であるKang Leeの研究を含む調査から明らかになったことは、嘘をつくことは標準的な成長の印であるということです。子供が嘘をつくのを見つける、親や教師は不安になる必要はない、子供たちは病的な嘘つきにはなることはないのだから、とLee 教授は述べています。教授は、過去15年間、子供が成長するに連れて嘘がどのように変化するのか、なぜある人は他の人に比べて嘘をつく回数が多いのか、同様に、どの要因が嘘つき行動を減少させるのか、という研究をしてきました。教授は言います、子供が嘘をつくのは新たな発達段階に到達したことを示すものである、と。

Sentence-completion items:

1. 発達心理学者は、嘘を.....から理解しようとしている。
2. 子供は.....を割ったときに嘘をつく。
3. 嘘をつくことは子供の.....成長の証である。
4. 教師は、子供が嘘をつくのをみて.....にならなくて良い。
5. 嘘をつく子供は、新たな.....段階に到達している。

Unattended passage A2 in English:

Toddlers who tell lies early on are more likely to do well later, researchers claim. The complex brain processes involved in formulating a lie are an indicator of a child's early intelligence, they add. A Canadian study of 1,200 children aged two to 17 suggests those who are able to lie have reached an important developmental stage.

Only a fifth of two-year-olds tested in the study were able to lie. But at age four, 90% were capable of lying, the study found. The rate increases with age to a peak at age 12. The director of the Institute of Child Study at Toronto University, Dr Kang Lee, said: "Parents should not be alarmed if their child tells a fib. "Their children are not going to turn out to be pathological liars. Almost all children lie. "It is a sign that they have reached a new developmental milestone. "Those who have better cognitive development lie because they can cover up their tracks." This was because they had developed the ability to carry out a complex juggling act which involves keeping the truth at the back of their brains. He added: "They even make bankers in later life."

Unattended passage A2 in Japanese:

早くから嘘をつく幼児は後々に成功する、と研究者は主張しています。嘘を形成する複雑な脳の処理過程は、子供の早期の知性の現れであると彼等は言います。1200人の2歳から17歳までの子供を対象にしたカナダでの研究によると、嘘をつくことが出来るということは、重要な発達段階に到達したということを示すものであるということです。研究に参加した2歳児の5分の一しか嘘をつくことが出来ませんでした。4歳になると、90%の子供が嘘をつくことが出来ました。発達の速度は、年を重ねるに従って加速し、12歳にピークに達します。トロント大学の児童研究所の所長、Kang Lee教授は次のように言います、親は子供が嘘をつく時、不安になる必要はありません。子供たちは病的な嘘つきになることは無いのです。ほとんど全ての子供が嘘をつくんですから。嘘をつくの、新たな発達段階に到達したことの印なのです。より良い認知発達をすると嘘をつくの、なぜならそういう人は自分の意図を隠すことが出来るからです。これは、彼等は脳裏に本心を隠すことを伴う、複雑で曲芸のような行動を実行する能力を発達させたからなのです。晩年にはそういう子供たちは銀行員にさえ馴れるかも知れないですよ。

2. A3 and A4 - LSA: 0.80

Attended passage A3 in English:

Scientists say they have found clear proof that meat from whales captured under Japan's whaling programme is being sold in US and Korean eateries. The researchers say they used genetic fingerprinting to identify meat taken from a Los Angeles restaurant as coming from a sei whale sold in Japan. They say the discovery proves that an illegal trade in protected species still exists. Commercial whaling has been frozen by an international moratorium since 1986. But a controversial exemption allows Japan to kill several hundred whales each year for what is termed scientific research. The meat from these whales is then sold to the public in shops and restaurants in that country. A team of scientists, film-makers and environmental advocates say they collected samples of whale meat being sold in sushi restaurants in both the US and South Korea late last year. A genetic analysis of meat found in Los Angeles showed that it was identical to meat from a sei whale being sold in Japan in 2007.

Sentence-completion items:

1. was used to identify where the whale meat came from.
2. Scientists discovered the existence of illegal trades in
3. An international moratorium on commercial whaling started in
4. A group of scientists, environmental advocates and found evidence of whale meat sold in the US and South Korea.
5. Meat in Los Angeles was to the meat sold in Japan in 2007.

Attended passage A3 in Japanese:

科学者は、アメリカと韓国の飲食店で日本の捕鯨プログラムで捕らえられたクジラの肉を販売しているという明らかな証拠を見つけたと発表しました。研究者は、彼らがロサンゼルスレストランから取られた肉が、日本で販売されたイワシクジラの肉であると認識するためにDNA鑑定法を使用したと報告しています。彼らは、この

発見が、保護種の不正取引がまだ存在していると立証することになると言っています。1986年以来商業捕鯨は国際的なモラトリアムによって凍結されています。しかし、論議を呼んだ控除で、日本は、毎年、科学調査と銘打ったことのために数100頭のクジラを捕獲することができます。そして、自国の店とレストランなどの一般にこれらのクジラの肉が販売されます。科学者のチーム、映画制作者、および環境支持者は、彼らが昨年後半で米国と韓国の両国のすし屋で販売されていた鯨肉のサンプルを集めたと言っています。ロサンゼルスで見つけられた肉の遺伝分析は、それが2007年に日本で販売されるイワシクジラからの肉と同じであることを示しました。

Sentence-completion items:

1. クジラ肉がどこから来たか判別するために.....が使用された。
2. 科学者は.....の違法取引が存在していることを発見した。
3. 商業捕鯨に関する国際的なモラトリアムは.....年に始まった。
4. 科学者、環境支持者、.....がアメリカと韓国で販売されたクジラ肉の証拠を見つけた。
5. ロサンゼルスで見つかった肉は、2007年に日本で売られていた肉と.....であった。

Unattended passage A4 in English:

The whale meat provided in sushi restaurants in the United States and South Korea, is likely to have been smuggled from Japan, revealed by the research by Oregon State University, published in an online edition of a science magazine in the UK on April 14th. Researchers say that the whale products distributed in Japan match the result of the DNA analysis. According to their research, the sei whale meat the research team obtained from the sushi restaurant in Los Angeles last October and whale products purchased in Japan between 2007 and 2008 had identical DNA. Furthermore, they investigated whale meat used in a sushi restaurant in South Korea

last June and September, and found that the meat they investigated included minke and fin whales in the Antarctic Ocean which should not be distributed in South Korea. Export and import of whale meat of scientific whaling is essentially prohibited by the Washington Convention. The research team says that whale meat of scientific whaling has been illegally traded and is requiring related agencies to do thorough investigations.

Unattended passage A4 in Japanese:

米国と韓国のすし店で提供されていた鯨肉が、日本から密輸された可能性が高いことが、米オレゴン州立大の調査研究でわかり、14日付英科学誌電子版に発表された。日本で流通していた鯨製品とDNA解析の結果が一致したという。調査によると、研究チームが昨年10月に米ロサンゼルスのすし店で入手したイワシクジラの肉と、2007～08年に日本国内で購入した鯨製品のDNAを鑑定したところ一致した。さらに研究チームは、昨年6月と9月に韓国ソウルのすし店が出した鯨肉を調べたところ、韓国では本来流通していないはずの南極海のミンククジラやナガスクジラなどが含まれていた。調査捕鯨の鯨肉の輸出入はワシントン条約で原則禁止されており、研究チームは「科学調査の名で捕獲された鯨が違法取引されている」として、関係機関に徹底調査を要求している。

3. B1 and B2 - LSA: 0.72

Attended passage B1 in English:

A new Japanese space probe is poised to launch toward Venus to help solve the enduring mysteries of the hellish, cloud-covered world, which has been often described as Earth's twin. But the ambitious spacecraft will have to wait for better weather on Earth. The Venus Climate Orbiter - also known as Akatsuki, which means "Dawn" in Japanese - was ready to launch from Tanegashima Space Center in Japan. But low clouds and foul weather prevented its scheduled liftoff at 5:44 p.m. ET Monday. The next launch attempt would come no earlier than Friday, Japan's Kyodo

news service reported. The probe will take on a two-year mission to study the weather and surface of Venus in unprecedented detail. "Once we can explain the structure of Venus, we will be able to better understand Earth," Akatsuki project scientist Takeshi Imamura said in a statement released by the Japan Aerospace Exploration Agency, or JAXA. "For example, we may discover the reasons that only Earth has been able to sustain oceans, and why only Earth is abundant in life."

Sentence-completion items:

1. People often describe Venus as Earth's
2. The spacecraft is waiting for
3. The next launch attempt will be after
4. Akatsuki is going to investigate Venus for
5. Researchers might find reasons why Earth has been able to keep its

Attended passage B1 in Japanese:

新しい日本の宇宙探査機は、しばしば地球の兄弟星として表現される、地獄のようで、雲がかった世界の火星の不朽の神秘を解明するために飛び立つ用意ができています。しかし、その野心に燃えた宇宙船は地球上での好天を待たなくてはなりません。火星気候探査機、またの名を日本語で暁という探査機は日本の種子島宇宙センターで飛び立つ用意ができていました。しかしながら、低くたれこめた雲と悪天候によって、月曜日の東部標準時午後5時44分に予定されていた発射が中止されてしまいました。日本の共同通信社は、次の発射は金曜日以降になるだろうと伝えました。探査機は、火星の気候と表面を前例に無いほど詳細に調査する2年間の任務に就きます。火星の構造が説明出来れば、地球のことがよりいっそう分かるだろう、と探査機暁プロジェクトの科学者である稲村武さんが日本宇宙航空研究開発機構の声明で述べました。例えば、地球だけが海洋を維持することが出来ているのか、また何故地球だけに生命が豊かにあるのかの理由が見つかるかもしれません。

Sentence-completion items:

1. 火星は地球の.....と称される。
2. 宇宙探査機は.....を待っている。
3. 次の発射は.....以降を予定している。
4. あかつきは火星を.....のあいだ調査する。
5. 研究者は、地球がなぜ.....を維持して来れたのか解明するかも知れない。

Unattended passage B2 in English:

Japan launched its first Venus probe satellite for a two-year mission on Friday. An H-2A rocket carrying the Venus climate orbiter called "Akatsuki" blasted off from a Japanese space centre in Kagoshima, southern Japan. Television pictures showed the craft lifting off and heading into space, jettisoning a solid-fuel booster on the way and finally letting slip the much smaller probe Akatsuki. The orbiter can circle around Venus for four years to examine its climate. Liftoff of the H-2A rocket took place at 6:58 a.m. and Akatsuki was successfully delivered into orbit 27 minutes later. Four small satellites developed by students and private-sector bodies were also put into orbit along with a "space yacht," Ikaros, which will be propelled using radiation from sunlight. The Japan Aerospace Exploration Agency (JAXA) had postponed the launch, originally planned for Tuesday, because of bad weather, but well within the deadline of 3 June imposed by the need to reach Venus to take up a particular orbit. Akatsuki is expected to reach Venus orbit in December.

Unattended passage B2 in Japanese:

日本は、金曜日に2年の任務のための国産初の火星探査衛星を発射しました。宇宙航空研究開発機構によると、暁と呼ばれる火星気候探査機を乗せるH-2Aロケットは、鹿児島県の日本の宇宙センターから飛び立ちました。テレビの画像は、ロケットが宇宙に向かって離陸し、途中で固形燃料ブースターを捨て、最後にロケットに比べかなり小さい探査機である暁の放出成功を映しました。探査機は、気候を調べるために火星の周りを4年間周回することが出来ます。H-2Aロケットの発射は午前6時

58分に行われました、そして、27分後に暁を軌道に乗せることに成功しました。また、学生と民間団体によって開発された4個の小型衛星が宇宙ヨットのイカロスと共に周回軌道に乗せられました。イカロスは、日光からの放射能を使い動力とします。宇宙航空研究開発機構(JAXA)は、悪天候のために、元々火曜日に予定していた発射を延期しました。しかし、特定の軌道に乗るために火星に6月3日までに到着する期限までには十分に間に合いました。暁は12月に火星軌道に達すると予想されています。

4. B3 and B4 - LSA: 0.70

Attended passage B3 in English:

People who carry a lot of weight around their middle are at increased risk of developing dementia, say researchers. A US study of more than 700 adults showed that being overweight is associated with smaller brain volume, a factor linked with dementia. More than 750,000 people in the UK have a form of dementia. The researchers from Boston University School of Medicine looked at people with an average age of 60 years old, 70% of whom were women. They measured body mass index, which is waist circumference. The results showed that as BMI increased, brain volume decreased - a finding that has been reported in other studies. But the findings also showed a closer connection between abdominal fat and the risk of dementia. The link between visceral fat around the central organs and smaller brain volume was independent of overall weight. Study leader Dr Sudha Seshadri concluded: "Although these findings are preliminary, they could improve our understanding of the mechanisms underlying the relationship of obesity with dementia, with potentially important implications for prevention strategies."

Sentence-completion items:

1. More than adults took part in the US study.
2. Being overweight has something to do with smaller size.
3. In the UK, more than people could suffer dementia.

4. weight doesn't have a relationship between visceral fat around the central organs.
5. Research findings have important implications for dementia.

Attended passage B3 in Japanese:

研究者は、お腹回りが重い人は認知症を発症する危険性が高いと発表しました。700人以上の成人を対象に行なった米国の研究によると、太りすぎのひとは、より脳の容量が小さいことを発見しました。これは認知症に関係する要因です。イギリスの75万人以上は認知症の型を持っています。ボストン大学医学部の研究者が平均年齢60歳で、その内70%は女性である集団を検査しました。彼等はBMIを測りました、BMIとは、お腹回りのことです。研究は、BMIが増加すると脳の容量が小さくなるという、他の研究でも報告されている結果を示しました。しかし、調査結果はお腹回りの脂肪と認知症の危険性との、より厳密な関係を示しました。体の中心にある臓器の回りにある脂肪繊維と、脳の容量が小さくなることの関連は、全体重とは関係ありません。研究リーダーのスーダ・セシャドゥリは次のように結論づけました、これらの結果は初期段階のものであるが、肥満と認知症の関係の背後にある仕組みをより理解するのに役立つし、予防策に対する重要な示唆を与えてくれる、と。

Sentence-completion items:

1.以上の方がアメリカでの実験に参加した。
2. 太り過ぎはより小さい.....のサイズと関係がある。
3. イギリスでは、.....以上の方が認知症に悩まされる可能性がある。
4. 体の中心にある内蔵脂肪と、.....体重は関係がない。
5. 研究結果は、認知症の.....に重要な示唆を与える。

Unattended passage B4 in English:

People with a bulging waistline in mid-life could face a higher risk of dementia and Alzheimer's in the senior years, a new study shows. Previous research has shown that having an apple-shaped body increases the risk of diabetes, stroke and heart disease, but this is the first time it has been linked to dementia and Alzheimer's. In the study, which was published Wednesday by the journal *Neurology*, people who were both obese and had a large belly were three times more likely to be diagnosed with dementia in later years than those of normal weight and belly size. The risk of dementia nearly doubled in those who were a healthy weight but still had a bulging waist, suggesting that fat accumulated around the midline is particularly unhealthy for the brain. The findings are particularly concerning in light of the rise in obesity rates in the United States. More than one-third of U.S. adults are obese and about half have abdominal obesity.

Unattended passage B4 in Japanese:

中年の出っ張ったお腹をしている人々は、老年期になると認知症とアルツハイマーの危険性が高まる、と最新の研究で明らかになりました。以前の研究によると、りんご形をしているボディーを持っていると糖尿病、卒中、および心臓病の危険が増加するということでしたが、それが認知症とアルツハイマーに関連付けられたのは、これが初めてです。水曜日に神経学の研究雑誌に載った研究では、肥満であり、大きいお腹を持っていた人々は、後年に標準体重と標準のお腹回りの人より認知症と診断される可能性が3倍ある、ということでした。健康体重でも出っ張ったお腹をしている人の認知症になる可能性は2倍で、お腹回りに蓄積された脂肪は特に脳にとって有害であるということです。調査結果は、アメリカの肥満の増加に特に関連している、とも示しています。アメリカの3分の1以上が肥満で、半分がお腹回りの肥満なのです。

5. C1 and C2 - LSA: 0.80

Attended passage C1 in English:

New hominid fossils of the new species about two million years ago were found in the north part of South Africa. The research team found 195 million to 178 million-year-old fossils of two bodies in a cave using satellite photos of Google. They estimated that one of the bodies would be an adult woman aged between twenty and thirty, and the other one a boy aged between eight and nine, both weighing about 30kg and about 127 centi-meters tall. They seem to be descendants of Africanus which is a kind of hominid called Australopithecus and ancestors of primitive men situated between apes and modern human beings. It appears that they are hominids during the period when apes spending most of the time on trees evolved into bipedal primitive men. Professor Gen Suwa at Tokyo University says, 'It is a discovery which will contribute to the understanding of the evolution of early hominids. However, it can be simply an individual difference between Africanus. We need to wait for further research.'

Sentence-completion items:

1. The research team used of Google to find the fossils.
2. One of the two fossils found was a boy and the other was an
3. The estimated weight of the fossils was 30kg and the height was cm tall.
4. The two fossils are of primitive men situated between apes and modern human beings and are descendants of Africanus
5. The professor at University of Tokyo points out that it is simply an

Attended passage C1 in Japanese:

南アフリカ北部で約200万年前の新種の猿人化石が見つかった。ウィットウォーターランド大などの研究チームが9日付の米科学誌サイエンスに発表した。チームは米検索大手グーグルの衛星写真を使って探索した洞窟で、195万～178万

年前の化石2体を発見。1体は20～30歳代の成人女性、もう1体は8～9歳の少年と見られ、いずれも体重約30キロ、身長127センチ程度と推定された。アウストラロピテクスという猿人の一種の「アフリカヌス」の子孫で、猿人と現生人類の間に位置する「原人」の祖先にあたるとみられる。樹上生活中心の猿人が、地上で二足歩行する原人に進化する時期の人類と考えられるという。諏訪元・東大教授は「初期人類の進化の理解に貢献する発見だ。ただ、アフリカヌスの中の個体差に過ぎないのではないか。今後の研究を待つ必要がある」としている。

Sentence-completion items:

1. 研究チームは、グーグルの.....を使って洞窟を検索した。
2. 発見された化石のうち、1体は少年で、もう1体は.....であった。
3. 化石の推定体重は約30キロで、身長は.....センチであった。
4. 2体の化石は猿人と現生人類の間の.....で、アフリカヌスの子孫である。
5. 東大教授は、今回の発見は.....に過ぎない、と指摘している。

Unattended passage C2 in English:

Hominid fossils of a new species of apes who are ancestors of human beings about two million years ago were found in a cave in South Africa. An international research team of researchers in South Africa and the USA named this ape of the new species 'Australopithecus Sediba.' In total, two fossils of Sediba apes, male and female each, were found in a stratum between 1.95 and 1.78 million years old and about 40km north from Johannesburg. The height of both fossils was estimated to be about 1.27 meters and the weight of the male was estimated to be about 27kg and the female about 30kg. The feature of their lower body muscles, e.g., those of the pelvis, is similar to that of hominids' and they are thought to be walking on their own feet. Professor Gen Suwa at the University Museum, the University of Tokyo, says, 'An interpretation that the fossils are the new species to understand the origin of hominids cannot be made yet, but this is a new and valuable discovery that will contribute to our understanding of the evolution of apes in South Africa.'

Unattended passage C2 in Japanese:

南アフリカ共和国の洞穴から約200万年前の人類の祖先である猿人の新種の化石がみつかった。同国や米国などの研究者でつくる国際チームはこの新種の猿人を「アウストラロピテクス・セディバ（セディバ猿人）」と名付けた。セディバ猿人の化石はヨハネスブルクの北約40キロにある洞穴の195万～178万年前の地層から男女1体ずつ計2体見つかった。身長はともに約1.27メートルで、体重は男性が約27キロ、女性が約33キロと推定された。年齢は、男性が10歳前後の子ども、女性が20代後半～30代前半。骨盤の筋肉の付き方など下半身の特徴は、ヒト属に近く、二足歩行していたと考えられる。東京大総合研究博物館の諏訪元教授も「『ヒト属の起源につながる新種』との解釈は現段階ではできないが、南アフリカにおける猿人の進化や、東アフリカも含む地域で見つかつている初期人類の進化の理解に貢献する貴重な新発見だ」と話している。

6. C3 and C4 - LSA: 0.86

Attended passage C3 in English:

From plastics to supermarkets, and from globalised industry supply chains to the layout of our towns and cities, almost every aspect of human life has been radically altered over the past 150 years by oil. Although cheap and plentiful oil has given many people choices and freedoms that never existed before, our addiction has been costly, measured in increased air and water pollution, rampant land use change, overharvesting of our seas, increasing greenhouse gas emissions and consequent climate change, acid rain and urban sprawl. It is time to look again at the technologies and risks involved in getting the oil to which our societies are addicted. Humans are inventing ever more ingenious ways to find and extract more difficult to access oil reserves in more extreme and generally more ecologically pristine regions. But getting oil from places such as the Arctic or deep under the ocean is not only technically difficult; it increases the risk of environmental damage, as we're currently seeing in the Gulf of Mexico.

Sentence-completion items:

1. Oil gave people and freedoms they never had before.
2. The effect of their addiction to oil can be seen in the consequent,
acid rain and urban sprawl.
3. It's necessary to think about the and risks when getting the oil.
4. People are trying to get oil in more and more ecologically pristine areas.
5. Getting oil in the and deep sea will increase the risk of damage to the
environment.

Attended passage C3 in Japanese:

プラスチックからスーパーマーケットまで、また、グローバル化している産業供給・チェーンから私たちの町と都市まで、人間の生活のほとんどが過去150年の間に油によって根本的に変わりました。安くて豊富な油は多くの人々に以前は全くなかったような選択肢や自由を与えましたが、私たちの油への依存は犠牲が大きく、水質汚染や大気汚染、激しい土地利用の変化、海産物の過剰収穫、地球温暖化ガスの増加、それに伴う気候変動、酸性雨、および都市の乱開発に現れています。私たちの社会が依存している油を得るのに伴う技術やリスクを今一度よく考えなくてはなりません。人類は、より極限の、また一般的に生態学的に新しい場所で入手しづらい油を探して抽出する巧妙な方法を発明しています。しかし、北極や深海のような場所から油を入手することは技術的に難しいだけでなく、メキシコ湾で垣間みられるように、環境破壊のリスクを上げてしまうことになるのです。

Sentence-completion items:

1. 油は人々にそれまで無かったような.....や自由を与えた。
2. 油への依存の影響が、.....、酸性雨、都市の乱開発に現れている。
3. 油を得る際の、.....やリスクを考えなくてはならない。
4. 人類はより.....の、生態学的に新しい場所で油を探そうとしている。
5.や深海で油をとると、環境破壊のリスクを上げることになる。

Unattended passage C4 in English:

The world changed one summer's day in 1858. In a field in Pennsylvania, in the United States, the world's first specially constructed deep well struck oil. Relatively easy to find, extract, process, store and transport, and above all cheap, liquid oil quickly became our most important energy source to cook, heat, cool and transport things. From plastics to supermarkets, and from globalised industry supply chains to the layout of our towns and cities, almost every aspect of human life has been radically altered over the past 150 years by oil. Although cheap and plentiful oil has given many people choices and freedoms that never existed before, our addiction has been costly. Increased air and water pollution, rampant land use change, overharvesting of our seas, increasing greenhouse gas emissions and consequent climate change, acid rain and urban sprawl. It is time to look again at the technology and risks in getting the oil our societies are addicted to.

Unattended passage C4 in Japanese:

世界は、1858年のある夏の日に変わりました。アメリカのペンシルベニアの原野で、世界初の特別に作られた深い井戸が石油を掘り当てました。比較的に見つけ易く、そして抽出、処理、貯蔵、そして運送し易い、そしてなにより安い、液体の油は料理、温める、冷やす、そして輸送のために最も重要なエネルギー源となりました。プラスチックからスーパーマーケットまで、また、グローバル化している産業供給・チェーンから私たちの町と都市まで、人間の生活のほとんどが油によって過去150年の間に根本的に変わりました。安くて大量にある油は、多くの人々に以前は全くなかったような選択肢や自由を与えましたが、我々の油への依存は犠牲を拡大しています。水質汚染や大気汚染、激しい土地利用の変化、海産物の過剰収穫、地球温暖化ガスの増加、それに伴う気候変動、酸性雨、および都市の乱開発などです。私たちの社会が依存している油を得るのに伴う技術やリスクを今一度よく考えなくてはなりません。

7. D1 and D2 - LSA: 0.76

Attended passage D1 in English:

The American President, Barack Obama, made a speech on April 15th at the NASA Kennedy Space Centre about space agency and revealed the goal of orbit manned flight to Mars by the mid-2030s. In his speech, he said, 'I believe we can send human beings to Mars orbit by the mid-2030s.' He aims to land the first man on Mars after the success of manned flight. This February Obama administration decided to retire the space shuttle within this year and the new rocket under development in the Constellation plan of the former administration of Bush. For several years, private rockets will be used to send people to the International Space Station. Hence, there have been arguments on the weakening leadership of the US and the loss of local employment. To amend the situation, President Obama showed a new schedule and announced plans that the manned spacecraft 'Orion' in the Constellation plan will remain and be used as an emergency spacecraft docked to the ISS.

Sentence-completion items:

1. The American president made a speech about
2. His administration decided to retire this year.
3. will be used to go to the ISS.
4. People have been arguing about the loss of
5. Orion will be used as an at the ISS.

Attended passage D1 in Japanese:

オバマ米大統領は15日、米航空宇宙局ケネディ宇宙センターで宇宙政策について演説し、2030年代半ばまでに、火星の有人周回飛行を行うとする新たな目標を初めて明らかにした。演説でオバマ大統領は「30年代半ばまでに人を火星軌道に送れると信じる」と述べ、有人飛行の成功後は、人が初めて火星着陸することを目指す。オバマ政権は今年2月、スペースシャトルを年内で退役させるとともに、ブッシュ前政権の「コンステレーション」計画で開発中の新ロケットも廃止するこ

とを決めた。数年間、国際宇宙ステーション(ISS)への飛行手段は、民間ロケットなどに頼ることになり、米国の指導力低下や、地元の雇用が失われることに批判が高まっていた。このためオバマ大統領は新たなスケジュールを示すとともに、コンステレーション計画のうち有人宇宙船「オリオン」だけは復活、ISSにドッキングさせ緊急避難用に使う方針も明らかにした。

Sentence-completion items:

1. オバマ大統領の演説の内容は.....についてであった。
2. 年内中に開発中の新ロケットも.....も廃止する予定である。
3. 今後、.....で国際宇宙ステーションへ飛ぶことになるため、
4.....が無くなること、またアメリカの指導力不足に批判が高まった。
5. 有人宇宙船は.....用に使われる。

Unattended passage D2 in English:

Barack Obama says it should be possible to send astronauts to orbit the planet Mars by the mid-2030s and return them safely to Earth. The US president made the claim in a major speech to staff and guests at the Kennedy Space Center in Florida. The White House has been under fire since announcing in February that it wanted to shut down Constellation, the current programme to replace the ageing space shuttle. Mr Obama said the proposed Orion crewship, its Ares launch rocket, together with the rest of the project's Moon-bound architecture were on an unsustainable path, costing too much money and taking too long to develop. The president claimed a refocused Nasa could achieve more, sooner than under Constellation. "What we're looking for is not just to continue on the same path; we want to leap into the future," he said. "We want major breakthroughs, a transformative agenda for Nasa." In the speech, the president did not change the broad outline of the vision for the US space agency he first expounded in his 2011 federal budget request.

Unattended passage D2 in Japanese:

バラク・オバマは、2030年代の半ばまでに火星の周回軌道に宇宙飛行士を送り、無事彼らを地球に返すことが可能であろうと述べました。米国大統領はフロリダのケネディ宇宙センターでの主要演説でスタッフと観客に向けてそのような声明を発表しました。2月にConstellation、古くなったスペースシャトルを取り替える現在の計画を停止すると発表して以来、ホワイトハウスは非難を受けています。オバマ氏は、提案されたオリオン宇宙船、宇宙船のアレス発射ロケット、そして残りのプロジェクトの月の行きの建築が維持不可能な経路にあったと言いました、それは開発するためにお金や時間がかかり過ぎていたからでした。大統領は、方向転換したNasaがConstellationよりさらに早く計画を実行できると主張しました。「我々がしようとしていることは同じことをし続けることではありません」。「未来に飛び込んで行きたいと考えています。」と、述べました。「私たちは、Nasaのために大きな進展、変化をもたらす指針が必要です。」演説で、大統領は彼が最初に2011年の連邦の概算要求で述べたアメリカ宇宙局の理想像の骨子を変えませんでした。

8. D3 and D4 - LSA: 0.78

Attended passage D3 in English:

A Harvard University team which looked at studies involving over one million people found just 50g of processed meat a day also raised the risk of diabetes. But there was no such risk from eating even twice as much unprocessed meat, such as beef, lamb or pork. This was despite the fact the two forms of meat have a similar fat content. Writing in the journal Circulation, the researchers speculated that given the similar quantities of cholesterol and saturated fats, the difference may be explained by the salt and preservatives added to processed meats. The team from Harvard School of Public Health looked at 20 studies involving more than one million participants from 10 countries. On average, each 50g serving of processed meat per day - the equivalent of a sausage or a couple of rashers of bacon - was associated

with a 42% higher chance of developing coronary heart disease and a 19% higher risk of diabetes.

Sentence-completion items:

1. Only of processed meat can raise the risk of diabetes.
2. Eating twice as much unprocessed meat such as beef,, and pork has no risk.
3. The difference between processed and unprocessed meats is and preservatives.
4. Harvard School of Public Health investigated studies on more than people.
5. Processed meat raises the risk of suffering diabetes by 19% and developing coronary heart disease by%.

Attended passage D3 in Japanese:

ハーバード大学の100万人以上を対象にした研究によると、一日にたった50グラムの加工肉を食べただけでも糖尿病になる危険性を高めるということが分かりました。しかしながら、例えば牛肉、ラム肉、もしくは豚肉などの加工されていない肉を2倍食べてもそのような危険性は見つかりませんでした。このことは、その二種類の肉が似たような脂肪を含んでいても関係がありませんでした。研究雑誌、血液循環に論文を書いた研究者は、コレステロールと飽和脂肪の量が似ていることを考えると、違いは加工肉に含まれている塩分や保存料にあるのではないかと推測しています。ハーバード公衆衛生学部の研究チームが10の国で100万人以上の被験者を対象にした20の研究を調べたところ、平均して一日当たり50グラムの加工肉を食べると冠動脈疾患になる可能性が42%高く、糖尿病になる可能性が19%高くなることが分かりました。

Sentence-completion items:

1.グラム加工肉を食べるだけで、糖尿病になる危険性が上がる。
2. 加工されていない牛肉、.....肉や豚肉を2倍食べても危険性は無い。
3. 非加工肉と加工肉の違いは、.....や保存料にある。
4. ハーバード公衆衛生学部が.....人以上を10カ国で調べた。
5. 加工肉は、糖尿病になる可能性を19%、冠動脈疾患になる可能性を.....%上げる。

Unattended passage D4 in English:

Eating processed meats, such as bacon, ham and sausages, can increase the risk of heart disease and diabetes, research suggests. A review by the Harvard School of Public Health examined 20 worldwide published studies involving more than a million people. It found a 42% higher risk of heart disease and a 19% increased risk of type 2 diabetes for each daily serving, on average, of 50g of processed meat. A 50g serving is roughly equivalent to two rashers of bacon or one hot dog. Unprocessed red meats, such as beef, pork or lamb, do not raise the risk. Researchers believe the levels of salt and preservatives in processed meat could explain the disparity. The study defined processed meat as any meat preserved by smoking, curing or salting, or with chemical preservatives added to it. "These results highlight the need for better understanding of potential mechanisms of effects and for particular focus on processed meats for dietary and policy recommendations."

Unattended passage D4 in Japanese:

ベーコン、ハムやソーセージなどの加工肉を食べると、心臓病と糖尿病の危険が増加することが研究で明らかになりました。ハーバード公衆衛生学部の研究チームが10の国で100万人以上の被験者を対象にした20の研究を調べたところ、平均して一日当たり50グラムの加工肉を食べると冠動脈疾患になる危険性が42%高く、糖尿病になる危険性が19%高くなることが分かりました。50グラムはベーコン2まいか、ホットドッグ一本と大体同じです。加工されていない牛、豚やラム

肉などの赤みの肉は危険性を上げません。研究者は、違いは加工肉に含まれている塩分や保存料にあるのではないかと推測しています。研究では加工肉を、ベーコン、サラミ、ソーセージ、ホットドッグ、加工生鮮食品、そして加工肉食品を含む、薫製、乾燥、塩漬け、または保存料が入った肉と定義しています。これらの結果は、加工食品の潜在的な影響の仕組みをより理解すること、そして食事療法や政策への提案の為に加工肉に特に焦点を置く必要性を強調しています。

Eight semantically unrelated pairs of passages (E1 & E2, E3 & E4, F1 & F2, F3 & F4, G1 & G2, G3 & G4, H1 & H2, and H3 & H4) (see Appendix A.3)

9. E1 and E2 - LSA: 0.16

Attended passage E1 in English:

Back in 1928 the British writer George Bernard Shaw wrote in his *Intelligent Women's Guide to Socialism and Capitalism* that 'A man is supposed to understand politics, economics and finance and is therefore unwilling to accept essential instruction.' He also said, 'A woman, having fewer pretensions, is far more willing to learn'. Let's look at what men and women actually save for. Research studies of women in North America have found that women are far more likely to save for their children's education and they are also more likely to save up in order to buy a house one day. The same studies have found that men, on the other hand, tend to save for a car, which by the way takes a surprisingly large amount of the household budget in North America. It is a fact that throughout the world, women are likely to live many years longer than men, so they need money to support them during this time. Since women are likely to be the ones left without a partner in old age, they may therefore have to pay for nursing care, because they don't have a spouse to look after them.

Sentence-completion items:

1. According to George Bernard Shaw, men are supposed to understand , economics and finance.
2. However, women are more prepared to about them.
3. Women tend to save for and a house.
4. Men tend to save for and for retirement.
5. Women who are left alone may have to pay for when they are old.

Attended passage E1 in Japanese:

英国作家のジョージ・バーナード・ショウは1928年に書いた「賢い女性の社会主義と資本主義のガイド」で、「男は政治、経済、そして財政を理解するように出来ているので、必要な教育を受けることをしる傾向にある」と述べました。また彼はこうも言っています、「主張をしない女性は、学ぶことにかなり意欲がある」、と。男性と女性が何に対してお金を貯めるのかを見てみましょう。北アメリカでの女性に関する研究調査で、女性は子供の教育に、またいつの日か家を買うために貯蓄をする傾向が強いということが分かりました。同じ研究において、一方で男性は車を買うために貯蓄をする傾向が強く、これは北アメリカの家計の驚くくらいの大部分を占めています。女性が男性よりも長生きするというのは世界的な事実です。そのため、女性は長生きの期間の生活を支えるためにお金が必要なのです。老後に一人残されるのは女性の方がありがちなので、女性は介護費用を払わなくてはならないかも知れません。それは、世話をしてくれる相方がいないからなのです。

Sentence-completion items:

1. バーナード・ショウ曰く、男性は.....、経済、そして財政を理解する。
2. しかし、女性はより.....とする。
3. 女性は.....や家を買うために貯蓄をする。
4. 男性は.....のために貯蓄をする。
5. 独り身の女性は、老後の.....を払わなくてはならない。

Unattended passage E2 in English:

There are two major areas that I will focus on in my talk: how vegetation can have a significant effect on urban climate, and how we can better plan our cities using trees to provide a more comfortable environment for us to live in. Trees can have a significant impact on our cities. They can make a city, as a whole, a bit less windy or a bit more windy, if that's what you want. They can make it a bit cooler if it's a hot

summer day in an Australian city, or they can make it a bit more humid if it's a dry inland city. In fact trees and planting of various kinds can be used to make city streets actually less dangerous in particular areas. The main difference between a tree and a building is a tree has got an internal mechanism to keep the temperature regulated. It evaporates water through its leaves and that means that the temperature of the leaves is never very far from our own body temperature.

Unattended passage E2 in Japanese:

今日は大きく二つのことに焦点を当てて話をしたいと思います。一つ目は、植林がどのように都市の気候に大きな効果をもたらすか、そして二つ目は木を利用して住み心地の良い環境を提供するための都市計画をどのようにしたら良いか、です。木は都市にとっても大きな影響を与えます。木は都市を全体的に、望み通りに、風を弱くも強くもすることが出来ます。オーストラリアの都市の夏の暑い日であれば、少し涼しく、また乾燥した内陸の都市であればすこし湿度を上げることが出来ます。実は、木や何種類もの植林によって特定の場所の通りの道の危険度を下げることが出来ます。木とビルの主な違いは、木は温度を循環させる内側の構造があるということです。それにより葉を通して水を蒸発させます、つまり、葉の温度は我々の体温と比べてかけ離れていないということなのです。

10. E3 and E4 - LSA: 0.3

Attended passage E3 in English:

You'll also find that to get the most out of the library you really do need to be computer literate. Many students do most of their research on the Internet and the library computers are permanently online. Clearly you can find lots on there but much of it is useless information as it is from highly debatable sources. You'll also find that the library has loaded several CD-ROMs onto the computers from specialist reference sources such as the MLA. It means we can expand what we offer you at very little extra cost and saves us having to invest in more and more books. Clearly

some of you will find the printed version more accessible as it sits on the shelves but I'm afraid the intention is to phase these out eventually. Naturally we do still have the full range of classic reference books, additional to the CD-ROMs, for you to use and there are several copies of each one. There is a restricted loan time on these so that they are not missing from the shelves for too long.

Sentence-completion items:

1. Students are required to be computer so as to take advantage of the library.
2. Much of the information found on the Internet comes from very
3. CD-ROMs prevent the library from having to in books.
4. The printed version will be more for some of the students.
5. Students need to be careful about a time when they borrow CD-ROMs.

Attended passage E3 in Japanese:

図書館を最大限活用するには、コンピュータでの読み書きが出来ることが大変重要です。学生の多くは調査研究のほとんどをインターネットで行ないます、そのため図書館のコンピュータは常時オンラインです。もちろん多くの情報をインターネットでみつけることができますが、そのほとんどは情報源が怪しいので、役に立たない情報です。また図書館ではMLAのような専門分野の文献のCD-ROMをコンピュータに設置しています。それによって本当に少しの費用で図書館が提供出来ることの幅を広げることが出来ますし、多くの本に投資しなくてもよくなるのです。書籍版の方が、本棚にあるので手に取り易いと思う人がいるかもしれませんが、図書館の意図としては最終的には書籍版を無くしていく方針です。当然のことながら、CD-ROMに加えて古い参考文献が広範囲に渡ってありますし、それぞれの複写版がいくつかあります。これらの本には本棚から長期間なくなることがないように、貸し出し期間が限られています。

Sentence-completion items:

1. 図書館を活用するには、コンピューターでの.....が重要である。
2. インターネットからの情報は、.....。
3. 書籍をCD-ROM化することで、書籍に.....しなくてすむ。
4. 書籍版の方が.....と感じる人もいる。
5. 古い参考文献は.....。

Unattended passage E4 in English:

The agreed targets for the UK mean that by 2008 we must reduce our carbon dioxide emissions by 12.5%, compared with 1990. And recycling can help to achieve that goal, in two main ways: the production of recycled glass and paper uses much less energy than producing them from virgin materials, and also recycling reduces greenhouse gas emissions from landfill sites and incineration plants. One problem is that there aren't enough 'drop-off' sites, that is, the places where the public are supposed to take their waste. Another difficulty is that toughened glass used for cooking doesn't fully melt at the temperature required for other glass, and so that also has to be picked out by hand. Glass is easy to recycle because it can be reused over and over again without becoming weaker. Two million tons of glass is thrown away each year, that is, seven billion bottles and jars; but only 500,000 tons of that is collected and recycled.

Unattended passage E4 in Japanese:

英国で決められた数値目標は、2008年までには、二酸化炭素排出量を1990年と比べて12.5%抑えなければならないことを意味します。そして、再利用は、2つの主な方法でその目標達成の役に立ちます：一つ目は、再生ガラスと再生紙の生産は元々の原材料から生産するより遥かに 少ないエネルギーを使用します、そして、また、再利用によって埋立地と焼却場からの地球温暖化ガスの放出を減少させることができます。問題の1つは、ゴミを運んでいく場所、つまり、ゴミ捨て場が十分に無いということです。別の問題としては、料理に使用される強化ガラスは、他のガラスに必

要である温度で完全に溶けるという訳ではないということです。毎年二百万トンのガラスが捨てられます、つまり70億個の瓶やコップが捨てられるのです。しかし、回収されて、再生されるのはその内50万トンだけなのです。

11. F1 and F2 - LSA: 0.27

Attended passage F1 in English:

What is marketing? Many people think of it simply as the process of selling and advertising. And this is hardly surprising when every day we are bombarded with television adverts, mail shots, and telephone sales. But selling and advertising are only two functions of marketing. In fact, marketing, more than any other business function, deals with customers. So perhaps the simplest definition is this one: marketing is the delivery of customer value and satisfaction at a profit. In other words, finding customers, keeping those customers happy and making money out of the process! The most basic concept underlying marketing is the concept of human needs. These include basic physical needs for things like food, as well as warmth and safety. Besides physical needs, there are also social needs - for instance, the need to belong and to be wanted. And in addition to social needs, we have the need for knowledge and self-expression, often referred to as individual needs.

Sentence-completion items:

1. People get TV ads, and telephone sales every day.
2. Marketing has two functions: selling and
3. Marketing is finding customers, making them happy, and out of the process.
4. Physical needs include food, warmth and
5. Need for knowledge and self-expression is called

Attended passage F1 in Japanese:

マーケティングとは何でしょうか？多くの人はマーケティングは販売と広告することであると単純に考えています。確かに私たちは毎日のようにテレビ広告、郵便広告、そして電話による販売を溢れるほど受けます。しかし、販売と広告はマーケティングの2つの機能にすぎません。事実、マーケティングはいかなる他のビジネス機能よりも顧客に対応する機会が多いです。それゆえ、おそらく最も簡潔な定義はこれです：マーケティングは、顧客に価値と満足感を与えて利益を得ることです。言い換えれば、顧客を探して、それらの顧客を幸せにして、その過程から利益を生むことです！最も基本的なマーケティングの概念は、人間の需要の概念です。これらは食べ物、暖かさ、および安全のような基本的かつ物理的な需要を含んでいます。物理的な需要に加えて、社会的な需要もあります。そして、社会的需要に加えて、私たちには、しばしば個人的需要という、知識と自己表現への需要があります。

Sentence-completion items:

1. 人々は、毎日テレビ広告、.....、そして電話による販売を受け取る。
2. マーケティングには2つの機能がある：販売と.....である。
3. マーケティングは、顧客を探し、幸福にし、その過程から..... ことである。
4. 物理的な需要は、食べ物、暖かさ、そして.....である。
5. 知識や自己表現への需要は.....と呼ばれている。

Unattended passage F2 in English:

Good morning, my name is Dr Mervin Forest and I specialise in management techniques and training. I've been invited here today to talk to you about the cost to the economy of bad management ... and what I would like to dwell on first is an area that has recently been exercising everyone and that is coercion in the workplace, or to put it more simply, bullying. It has been estimated that bullying at work costs the British economy up to four billion pounds a year in lost working time and in legal fees. And with the problem apparently on the increase, it is time that managers took

on board what is happening. I would like to think that what is perceived as bullying is nothing more than lack of experience, insecurity or lack of awareness on the part of managers, and not a conscious effort to attack someone, but that is perhaps a case of, of ... my being naive, or over-hopeful. Before we break up into groups to look at the first task on the handout you've got, I'd like to give you a start with some of the main bullying methods that have been identified so far.

Unattended passage F2 in Japanese:

おはようございます、私はマービン・フォレストと言います。経営技術と養成を専門としています。今日は、悪い経営が財政にもたらす支出について話すように招かれました。始めにお話ししたいのは、皆さん全員に影響することで、仕事場での威圧とも言う、もっと簡単に言うと、仕事場でのいじめについてです。仕事場でのいじめによって働く時間が減り、弁護士にかかる費用などで、イギリスの経済に年間で40億ポンドの損失を被っていると見積もられています。どうやらそのような問題は増えているので、経営者はそろそろいじめ対策に乗り出さなくてはなりません。いじめと受け取られていることは、経営者側の経験のなさや、認識が欠けているからにすぎず、誰かを攻撃しようという意識的な行為ではない、と思いたいのですが、それはもしかしたら私が甘いのか、希望を持ち過ぎているからなのでしょう。グループに分かれて手元の資料の最初の課題に取り組む前に、今までのところ特定されている主ないじめ方の概略をお話ししたいと思います。

12. F3 and F4 - LSA: 0.26

Attended passage F3 in English:

By the nineteenth century London was the busiest port in the world, and this became the main source of employment in the East End. Those who could afford to live in more pleasant surroundings moved out, and the area became one where the vast majority of people lived in extreme poverty, and suffered from appalling sanitary conditions. At the beginning of the century, living conditions for the majority of

working people in East London were very basic indeed. Houses were crowded closely together and usually very badly built, because there was no regulation. But the poor and needy were attracted by the possibility of work, and they had to be housed. Few houses had electricity at this time, so other sources of power were used, like coal for the fires which heated perhaps just one room. Of course, the smoke from these contributed a great deal to the air pollution for which London used to be famous. A tiny, damp, unhealthy house like this might well be occupied by two full families, possibly including several children, grandparents, aunts and uncles.

Sentence-completion items:

1. The port in London became the main source of
2. Many people lived in extreme in the East End.
3. Houses in East London were very
4. People in London used to use coal which could heat only
5. These tiny and unhealthy houses were occupied by two

Attended passage F3 in Japanese:

19世紀までロンドンは、世界で最も忙しい港でした、そして港での仕事がイーストエンドでの主な雇用源になりました。より良い環境に住む余裕がある人は引っ越しをし、残った人の大部分は極貧の生活をし、ひどい衛生状態の暮らしを余儀なくされました。19世紀の東ロンドンの大部分の労働者階級の人々の生活はかなり簡素なものでした。家は隣同士とても近く混雑していて、規則が全くなかったので、ひどい建てられ方をしていました。しかし、生活困窮者は仕事が手に入る可能性、また住み込みで働くことに引きつけられました。当時は電気が通っている家はほとんどなかったため、他の資源が利用されました。例えば、部屋を一つしか暖められないほどの炎しか作れませんでした、石炭が利用されました。当然、このような資源から出る煙が、以前の悪名高いロンドンの大気汚染の大きな要因となりました。このような小さく、湿っていて、不健康な家は、恐らく、子供、祖父母、おば、おじを含む2つの家族に使用されていたのでしょう。

Sentence-completion items:

1. ロンドンの港が主な.....源となった。
2. イーストエンドでは多くの人が極度に.....生活をしていた。
3. 東ロンドンの家は.....をしていた。
4. ロンドンの人々は、しか温められないほどの炎しか作れない石炭を使っていた。
5. 小さく不健康な家は、に使用されていた。

Unattended passage F4 in English:

Do you know what Prince Charles, Seve Ballesteros and Elizabeth Taylor have in common? They all suffer from chronic back pain. In fact, bad backs are one of the most common health problems today, affecting people in all walks of life. The most recent available figures show that about a quarter of a million people are incapacitated with back pain every day. The majority of our patients at the clinic tend to be women. They are especially vulnerable because of pregnancy but also because of osteoporosis, which I personally believe to be the major cause of problems for women. I have many women patients who say they have completely given up exercise because the pain makes them so miserable. But of course that starts up a vicious circle. Bed rest, giving up exercise and pain killers are traditional responses to back pain but, although there are many excellent drugs on the market, at our clinic we are beginning to realise the unique benefits of relaxation therapy.

Unattended passage F4 in Japanese:

あなたは、チャールズ皇太子、セベ・バレステロス、およびエリザベス・テイラーの共通点が何か知っていますか？ それらは皆、慢性腰痛に苦しんでいるということです。実は、ありとあらゆる職業の人々に影響しているのが、腰痛で、今日の最も一般的な健康問題の1つです。最新の統計によると、約25万人が毎日腰痛で悩まされています。診療所の患者の大部分が、女性です。彼女達は妊娠のため特に体を壊しやすいのですが、骨粗鬆症が女性に関する問題の主な原因であると私は個人的に

考えています。痛みでとても惨めになるので、運動を完全にやめたと言う多くの女性患者がいます。しかし、当然のことながら、悪循環に陥ってしまいます。ベッド休養、運動をしないこと、および鎮痛剤は背痛への正当な対処法ですし、市販には素晴らしい薬が多くありますが、診療所では、リラックス療法に独特の効能があることを発見しました。

13. G1 and G2 - LSA: 0.29

Attended passage G1 in English:

Although there is a Section Manager for each part of the library, they are very busy and so, if you do get stuck looking for things, you should ask the relevant Cataloguing Assistant. As your Training supervisor, I just oversee your induction and will not be around after this initial week. Some of you may be interested to know that the library is offering specialised training sessions on writing a dissertation. Obviously this is not relevant to those of you who are undergraduates; it is just for postgraduates. Your tutors will tell you at the outset how to set out the chapters they require but you will need to ask them how they would like you to organise the bibliography because it varies depending on your subject area. When you've got something together the trainer here will look through the draft version for you to see if it's OK. And, one final point, for those of you who have registered from abroad, we can offer individual sessions on dissertations if you feel you need them. If you require language lessons then they are available from the International Centre next to the Law Department.

Sentence-completion items:

1. The role of the supervisor is take care of the students'
2. Only can take special training sessions on writing a dissertation.
3. The way the is organised is different in each subject.
4. Students from can have individual sessions on dissertations.

5. Language lessons are provided in the International Centre next to the
Department.

Attended passage G1 in Japanese:

図書館には各部署に部局長がいますが、彼等は非常に忙しいので、資料を探すときに困ったことがあれば関連部署のカタログアシスタントに聞いて下さい。私は指導教官として、皆さんの研修を監督するだけで、来週以降はいませんので、そのつもりでいて下さい。図書館が提供している論文執筆の特別訓練に関して興味がある方がいるかも知れませんね。言うまでもなく、これは学部生対象ではありません。大学院生のみ提供されています。皆さんの指導教官が最初に論文の章設定の仕方を指導してくれると思いますが、参考文献の整理の仕方は専門分野によって違うので、指導教官に聞く必要があるかもしれません。何か書き終えたものがあれば、図書館の指導員が原稿を読み大丈夫かどうか確かめてくれます。海外から入学されたかた向けですが、論文の個人指導を受けることができます。語学の授業が必要でしたら、法学部の隣にある国際センターから利用可能です。

Sentence-completion items:

1. 指導教官の役割は、新入生の.....を監督することである。
2. 論文執筆の特別訓練を受けることができるのは.....だけである。
3. 専門分野によって.....の書き方が異なる。
4.からの学生は論文の個人指導を受けることができる。
5. 語学の授業を受けられるのは、.....の隣の国際センターである。

Unattended passage G2 in English:

Oddly enough, half the glass that's collected is green, and a lot of that is imported, so more green glass is recycled than the UK needs. As a result, new uses are being developed for recycled glass, particularly green glass. A company called CLF Aggregates makes a product for roads. For recycling paper, Britain comes second in

Europe with 40%, behind Germany's amazing 70%. Papersave, currently sells this to farmers as a soil conditioner. Pacrite recycles all sorts of things, from bottles to car bumpers, and one of its most successful activities is recycling plastic bottles to make containers which are used all over the country to collect waste. The Save-a-Cup scheme was set up by the vending and plastics industries to recycle as many polystyrene cups as possible. At the moment 500 million polycups are collected, processed and sold on to other businesses, such as Waterford, which turns the cups into pencils, and Johnson & Jones, a Welsh-based firm, which has developed a wide variety of items, including business cards.

Unattended passage G2 in Japanese:

不思議なことに、回収されたガラスの半分が緑色であり、その多くが輸入されているので、英国が必要とするよりも多くの緑色のガラスが再利用されます。CLF Aggregatesと呼ばれる会社では、道路製品を作っています。再生紙に関しては、ドイツの驚くべき70%に次いで、英国は40%で欧州で2番に位置しています。Papersaveという会社では、現在土壌調整剤として農業者にクズ紙を売っていますが、その臭いからすぐに差し止められるでしょう。Pacrite はビンから車のバンパーまでいろいろなものを再生します、そして、最もうまくいっている活動の1つは、全国で廃棄物を集める容器を製造するため、ペットボトルを再利用していることです。Waterford では、コップから鉛筆を作っています。Johnson & Jones では、名刺を含む様々な 製品を開発しました。

14. G3 and G4 - LSA: 0.27

Attended passage G3 in English:

Antarctica is a place of extremes - the highest, coldest and windiest continent and over fifty-eight times the size of the UK. The ice-cap contains almost 70% of the world's fresh water and 90% of its ice, but with very low snowfall, most of the continent technically falls unbelievably into the category of desert! Research and

exploration has been going on in Antarctica for more than two hundred years, and has involved scientists from many different countries, who work together on research stations. Here science and technical support have been integrated in a very cost-effective way. The research stations are really self-contained communities of about twenty people. There's living and working space, a kitchen with a huge food store, a small hospital and a well-equipped gym to ensure everyone keeps fit in their spare time. Supplies were brought to us on large sledges from a ship fifteen kilometres away at the ice edge.

Sentence-completion items:

1. Antarctica is over times the size of the United Kingdom.
2. Most of the land is categorised as
3. In research stations, and technical support are integrated.
4. The research stations have a kitchen, a and a well-equipped gym.
5. Supplies were brought to the station from a

Attended passage G3 in Japanese:

南極大陸は極寒の地です--最も標高が高く、最も気温が低く、最も風の強い大陸で、イギリスの面積の58倍以上もあります。万年雪は世界の淡水のおおよそ70%と氷の90%を含んでいますが、大陸の大部分は信じられないことですが、正式に言うと砂漠の範疇に入ります！多くの外国からの科学者が関わっており、科学者たちは研究基地で協力して研究をします。ここでは、科学と技術援助は経済的に非常に優れた方法で統合されています。研究所は約20人が生活している、まさに自給自足の地域社会です。生活、そして働く場所、沢山の食料を蓄えることができる台所、小さな病院、そして、余暇に健康を維持するために、設備の整った体育館があります。物資は15キロメートル離れた船から大きいそりで輸送されて来ました。

Sentence-completion items:

1. 南極はイギリスの.....の大きさがある。
2. 大陸の大部分は.....として分類されている。
3.は技術援助と統合されている。
4. 基地には宿泊施設、仕事をする場所、台所、.....と体育館がある。
5. 物資は15キロメートル離れた氷棚の.....からソリでゼロワン基地まで運ばれる。

Unattended passage G4 in English:

The research indicates that at present for women it takes a crisis to make them think about their future financial situation. Even women in their early twenties need to think about pensions, for example, and with increasing numbers of women in professional positions there are signs that this is beginning to happen. Then research also suggests that women avoid dealing effectively with their economic situation because of a lack of confidence. The best way for them to overcome this is by getting themselves properly informed so they are less dependent on other people's advice. A number of initiatives have been set up to help them do this. This College, for example, is one of the educational institutions which offers night classes in Money Management, and increasing numbers of women are enrolling on such courses. It is usually advised that at least 70% of a person's savings should be in low-risk investments but for the rest, financial advisors often advise taking some well-informed risks.

Unattended passage G4 in Japanese:

研究によると、現在、女性が将来の財政状況を考えるには、危機的状況に陥らなくてはならないそうです。例えば20代前半の女性でさえ年金のことを考えなくてはなりませんし、専門的な地位で女性が増えていることから、このことは起こり始めていると言えます。そして、女性は自信のなさから財政状況に対処することを避けるようです。これを打開する最善の策は、適切な情報を得るということ

です。それにより、他人の助言にあまり依存しなくても済むようになります。女性がそのようなことが出来るように、様々な取り組みが行なわれています。例えば、この大学は、マネーマネジメントの夜間講義を行っている教育機関の一つで、そのようなコースを履修する女性が増えています。少なくとも個人貯蓄の70%は低リスク投資に回すべきだということが言われていますが、残りに関しては財政アドバイザーは、事情が分かっているリスク投資を勧めています。

15. H1 and H2 - LSA: 0.15

Attended passage H1 in English:

Many believe that the story first began in America in 1877, when two friends were arguing over whether a horse ever had all four feet or hooves off the ground when it galloped. To settle the bet, a photographer was asked to photograph a horse galloping and the bet was settled because you could see that all the hooves were off the ground in some of the photos. What was even more interesting was that if the photos were shown in quick succession the horse looked like it was running - in other words 'moving pictures.' The person who became interested in taking the moving pictures to its next step was the famous American inventor Thomas Edison. Actually, he didn't do the work himself but rather asked a young Scotsman in his employ to design a system. Now this young fellow was clever because the first thing he did was study other systems of moving pictures and then put all the existing technologies together to make the first entire motion picture system.

Sentence-completion items:

1. What the two friends were arguing about was whether its four feet or
would be off the ground when a horse 2.
3. When the pictures seen in quick, the horse looked like it was running.
4. The system of moving pictures was developed by a
5. The first complete motion picture system was invented by integrating all
the

Attended passage H1 in Japanese:

多くの人が、そのお話が1877年にアメリカで最初に始まったと信じています。その時、2人の友人が、馬が駆けている時、すべての4本の足かひづめが地面から離れていたことがあったかどうか議論していました。賭けに決着をつけるため、写真家が馬の駆けているときの写真を撮るように頼まれました。何枚かの写真ですべてのひづめが地面から離れていたのもので、賭けは決着しました。さらにおもしろかったことは写真を立て続けに表示すると馬が走っているように見えたということです、つまり、活動写真です。活動写真を次の段階へ進めることに興味を持ったのは、かの有名なアメリカの発明家、トーマス・エジソンでした。実は、彼は自分でそれに着手したのではなく、彼が雇っていた若いスコットランド人の男性にシステム開発を頼んだのでした。その彼は賢く、活動写真の他のシステムを学ぶことを最初にし、そして、次にその当時存在していた技術を統合し、最初の完全な活動写真のシステムを作ったのです。

Sentence-completion items:

1. 二人の友人が議論していたのは、馬が.....いる時、4つの足全てか、
2.が地面から離れているかどうかだった。
3. 写真を.....に見ると、馬が走っているように見えた。
4. 活動写真のシステム開発をしたのは.....の男性だった。
5. 当時.....を統合し、完全な活動写真のシステムを作った。

Unattended passage H2 in English:

In today's lecture I'm going to continue the theme of animal communication, and I'm going to describe some of the latest research into the largest of all land animals. And that is the elephant, of course. Let me begin by briefly outlining the structure of elephant society. Elephants live in layered societies. The basic family unit is formed of small groups of adult females, who are related to each other, and their young of

both sexes. Now the females remain in their families for life, they're highly social, but male elephants leave their families at about fourteen years of age. They travel alone or congregate in small, loose groups with other males, occasionally joining a family on a temporary basis. The family unit, on the other hand, often contains three generations, and it can remain stable for decades, or even centuries. Then ... each family associates with between one and five other families, probably consisting of their more distant relatives. Scientists call these groups of families 'bond groups,' and bond groups belong, in turn, to even larger groups, called clans.

Unattended passage H2 in Japanese:

今日の講演では、動物の意思疎通について前回の続きを、そして、陸上生物の中で最も大きい動物についての最新の研究を紹介したいと思います。勿論、ゾウについてです。ゾウの社会について簡単に説明させて下さい。ゾウは階層社会の中で生きています。基本的な世帯は、大人のメスゾウの小さな集団から出来ていて、彼女らはお互いに親戚の関係で、その集団にはオスメス両方の若いゾウもいます。メスのゾウは家族の集団の中に一生残っていますが、オスのゾウは14歳頃になると家を出ます。彼等は一人で旅をしたり、小さく、関わりの少ない他のオスのゾウがいる集団に入ったり、一時的に家族に加わることもあります。一方で、世帯はしばしば三世代家族になり、その世帯は何十年も、もしくは何世紀も安定した家族になることがあります。各家族は、遠い親戚で構成されている一から五つの他の家族と交流します。科学者はこの家族の集団をボンドグループと呼びます。そしてこのボンドグループは順番に更に大きな部族と呼ばれる集団に属するのです。

16. H3 and H4 - LSA: 0.34

Attended passage H3 in English:

Good afternoon, my name is Dr Charles Butt and I shall be giving you a series of lectures on productivity and work practices over the coming weeks. There will be ten

lectures in the mornings as part of this course and, in addition, there will be three lectures in the evenings from six to eight which will be given by outside speakers.

I would like first to look at a recent report on life at work. The report shows that the average British worker takes less than half an hour for lunch, 27 minutes to be precise, and that sick leave is on the increase. The drop in the length of time spent on lunch was nine minutes when compared to last year, down from 36 minutes. According to the report, this is the first time that the average lunch break has fallen below half an hour. As regards sick leave, you can see that the average figure is ten days per year, that's up by one day in 2002 compared to 2001. While physical illness was given as the most common reason for absence in the case of non-manual workers, stress was the most common cause of long-term absence.

Sentence-completion items:

1. In the lecture, and work practices will be talked about.
2. In total, there will be lectures per day.
3. Average British workers spend for lunch.
4. The drop in the length of time for lunch is 9 minutes compared to
5. The most common cause of long-term absence is stress, and is for non-manual workers.

Attended passage H3 in Japanese:

こんにちは、私の名前はチャールズ・バットです、これから数週間の間、生産性と業務の実施に関する講演をしていきます。このコースでは、朝には10の講義があり、更に、学外からの講師による6時から8時までの夜の講義が3つあります。まず始めに、普段の仕事場に関する最新の調査を見ていきたいと思います。調査によると、平均的なイギリス人労働者は、昼食に30分以下、正確に言うと27分しか費やさず、その傾向が強くなっています。昼食に費やす時間の下がり幅は去年に比べて9分で、36分から下がっています。その調査によると、昼食時間が30分以下になったのは初めてだそうです。病気休暇に関して見てみると、平均して年に1

0日間で、2001年に比べ2002年で1日増えています。非肉体労働者の欠勤の理由として体調不良がもっとも良くある理由ですが、長期欠勤のもっとも一般的な理由はストレスによるものです。

Sentence-completion items:

1. 講演では、.....と業務の実施を扱う。
2. 朝晩合わせて合計で.....の講義がある。
3. 平均的なイギリス人労働者は、お昼休みに.....しか使わない。
4.に比べて9分下がっている。
5. 長期欠勤の主な理由はストレスだが、非肉体労働者の欠勤の理由は.....である。

Unattended passage H4 in English:

I'm here today to talk about a project to save a type of mouse known as a dormouse. We can still find the dormouse in this area, but in the last few decades the number of dormice has seriously declined, not just in this country but across the world. There are several reasons for this - loss of habitat, climate change, competition for food. The aim of the first stage of our project is simply to identify specific locations where dormice are still to be found, and estimate the number we have here. The dormouse is a very attractive, very small mammal - it only weighs about the same as a couple of pound coins. It's bright golden in colour, and it has a thick furry tail and big black eyes. Now, you've probably all seen a picture of a dormouse, but you're very unlikely to have seen a real one because they're strictly nocturnal. Also, they hibernate from October to April, so it's not around at all for about half a year.

Unattended passage H4 in Japanese:

ヤマネとして知られている一種のねずみを救うためのプロジェクトに関して話すために、私は今日ここに来ました。私たちはこの地域でまだヤマネを見つけることができますが、ここ数10年間で、ヤマネの数はこの国だけで低下したのではなく、世

界中でかなり低下しました。これにはいくつかの理由があります。生息地の損失、気候変動、食料競争です。私たちのプロジェクトの第一段階の目的は、ヤマネがまだ見つかる特定の場所を明らかにして、ここにいるヤマネの数を見積もることです。ヤマネは、非常に魅力的で、非常に小さい哺乳動物です。それは2、3のポンド貨幣とほぼ同じくらい重さがあるだけです。ヤマネは金色で、厚い柔毛に覆われたしっぽと大きい黒い目をしています。みなさんは、たぶんヤマネの写真を見たことがあると思いますが、夜行性であるので、本物を見たとはきっと無いと思います。また、ヤマネは10月から4月まで冬眠するので、半年間は見かけることは無いのです。

A.5: Reading Span Test (ESL) stimuli

The first two sets of sentences in the two-sentence condition are for a practice session. The following five sets of sentences in the two-, three-, four-, and five-sentence conditions are for the actual testing sessions.

Practice session: Two sets of sentences in the two-sentence condition

Set 1:

Practicing typing is not very difficult.

Music always provides us with pleasure and comfort.

Set 2:

Some people can see red apples in their dreams.

The boy swam in the river this summer.

Five sets of sentences in the two-sentence condition

Set 1:

The boys got together in the cave at midnight.

The man's dream was to create his own baseball field.

Set 2:

The medical students decided to conduct a dangerous experiment.

The lonely soldier's only friend was the grey wolf.

Set 3:

The student came to New York to enter college.

For several reasons, the police kept an eye on the man.

Set 4:

The woman lived her life as a famous artist.

Now the people can no longer use their own language officially.

Set 5:

The boy bought a new suit to attend the meeting.

Due to the scandal, he lost his job and his wife.

Five sets of sentences in the three-sentence condition

Set 1:

The policeman saved the child from the drug dealer.

The old couple left the dinner party without eating anything.

An innocent man was arrested and charged with murder.

Set 2:

The man gave the elderly woman a ride to the church.

The three men found it difficult to catch the evil monster.

July fourth was the day the brave young man was born.

Set 3:

The moon was the place he had always wanted to visit.

He overcame his handicap and succeeded as a writer.

Due to the bad weather, the airplane crashed when landing.

Set 4:

The patients had been considered hopeless until the drug was invented.

The boy often went to the theatre to see movies.

Whenever Harry saw Sally, they got into a bitter argument.

Set 5:

The detective finally made good friends with the police dog.

His destination was a small pacific island with a big mountain.

He had to sell five cars in only two days.

Five sets of sentences in the four-sentence condition

Set 1:

The rich but lonely man fell in love with the beautiful woman.

The man wanted to tell his girlfriend his real identity.

Since he really liked the yellow hat, he always wore it.

He began a distinguished career as a car racer.

Set 2:

The time machine crashed into a train and broke into pieces.

Her health became worse after she gave birth to her baby.

The audiences became angry when the child spoiled the play.

The couple's fight would probably be best described as a war.

Set 3:

She saw a woman who was sitting behind the counter.

The two countries chased the submarine for very difficult reasons.

The child defended his home against the heavy storm.

A best selling author was disturbed by his fan.

Set 4:

The man fell into the swimming pool from the eleventh floor.

The station was where the two had met for the first time.

They looked so different that nobody believed they were twins.

The French man married her just to become an American citizen.

Set 5:

Unlike many others, they had the courage to speak out.

They were happy when the millionaire invited them to his house.

They rented their house to him without knowing he was crazy.
The boy rescued the dying dog from the cold Alaska weather.

Five sets of sentences in the five-sentence condition

Set 1:

They found the boy standing in front of the post office.
Everybody thought that the young boxer was born to win.
She looked at the flowers which were lying in the box.
Being the daughter of a famous actress caused her a lot of problems.
The men in that family have been working at the hotel.

Set 2:

Their passionate love lasted only for nine and a half weeks.
The old man invited five children to his chocolate factory.
The scientist panicked when he failed to pass the examination.
The four heroes were named after famous Italian painters.
The soldier had strange visions while he was dying.

Set 3:

The young man listened carefully to her beautiful voice.
Leisure is now regarded as an important part of contemporary life.
One day he talked to a group of people from a foreign country.
In 1960, only about one third of the population used the radio.
To protect his girlfriend, the murdered banker returned as a ghost.

Set 4:

She was shocked when she discovered her boyfriend's strange hobby.
He saw a woman who was talking with his friend.
Nowadays people spend more time away from their jobs than ever before.
Though it was raining, there was much traffic on the street.

This is a story about a priest and his pupils.

Set 5:

One day he had to go away for a day or two.

I usually take an early train so that I can get a good seat.

He resolved to walk as long as his legs would carry him.

It was really painful for them to stop using their own language.

I said nothing, which made him angrier.

A.6: Self-report questionnaire

This questionnaire asked the participants' age of L2 acquisition, length of L2 learning, current age, gender, handedness, major study at university, amount of exposure to each language in listening, reading, writing and speaking, and histories of taking English proficiency tests such as IELTS.

1. 英語学習（習得）開始時期は？ (When did you start learning English?)

幼稚園より以前 (before preschool) (歳頃) (age)

幼稚園 (in preschool) (歳頃) (age) 小学校 (primary school) (年生) (grade)

中学校から (junior high school)

2. 英語学習歴は (How long have you been learning English?)

() 年 (years) () ヶ月 (months)

3. 年齢 (age) () 歳 (years) () ヶ月 (months)

性別 (gender) 女性 (female) 男性 (male)

4. 利き手は (handedness) 1 右手 (right) 2 左手 (left)

5. 専攻分野 (major study) (大学 (university) or 大学院 (graduate school))

(年生) (year) ・ 専攻： (name of major study)

6. 普段、日本語と英語を1日でどれくらいの頻度（何時間ほど）で使用していますか。(For how many hours a day do you use both English and Japanese in listening, reading, writing, and speaking?)

日本語 (Japanese)：聴く (listening) (時間 (hours)) 読み (reading) (時間 (hours))

書き (writing) (時間 (hours)) 話す (speaking) (時間 (hours))

英語 (English)：聴く (listening) (時間 (hours)) 読み (reading) (時間 (hours))

書き (writing) (時間 (hours)) 話す (speaking) (時間 (hours))

7. IELTS (Academic Module)を受けた回数 (How many times have you taken IELTS?)

() 回 (times)

最近（過去２年以内に）受けた際の各セクションのスコアとBand Scoreを教えてください。
(Please tell me your score in each section and Band Score in the last two years.)

Listening () Reading () Writing () Speaking () Band Score ()

TOEFL iBT:

Listening () Reading () Writing () Speaking () Band Score ()

TOEFL PBT:

Listening () Reading () Writing () Speaking () Band Score ()

TOEIC:

Listening () Reading () Total Score ()

英検を受けたことがある方は何級を合格されたか教えてください。(If you have taken
EIKEN, please tell me the grade you passed.) () 級 (grade)

ご協力ありがとうございました。(Thank you very much for your cooperation.)

A.7.: Experiment instructions

The following instructions were used for tasks used in Experiments 1, 2, 4, and 5. For these four experiments, whether preferred or non-preferred ear had to be used, and whether note-taking was allowed or not, was also explained at the beginning and at the end of an explanation of the BDL task, respectively. Instructions for Experiment 3, 6, and 7 where participants had to switch their ears are added in the instruction for the BDL task. All the instructions were given both orally and shown in the test sheets and Keynote slides. Emphases and clear explanations on instructions participants would not understand straight were made where necessary.

1. Earedness questionnaire

You will be given three questions regarding your ear preference when you use your mobile phone in general, in English, and in Japanese. Judge whether you prefer to use your left or right ear to each question with a tick. Then calculate the total sum of your ratings and indicate your ear preference.

2. English proficiency test

You will be given thirty questions to assess your English proficiency. Be sure to read the questions carefully because there are several types of questions such as multiple-choice questions, those in which you need to write a word, and those in which you write the missing part of the word. You will have 10 minutes to finish the test. If you have not finished after 10 minutes, you are given a few more minutes, but no more than 3 minutes.

3. Reading Span Test (ESL)

You will see five sets of sentences ranging from two- to five-sentence conditions on the screen. Your task is to read each sentence aloud while remembering the sentence-final word for later recall. For example, in the two-sentence condition you read aloud two sentences one by one. I will show the second sentence as soon as you finish

reading the first one. After reading them, write down words at the end of each sentence in the order they appeared in the spaces provided on your answer sheet. So, you cannot write the word you most recently read first. Misspellings are counted as errors, so make sure you write the words accurately. To proceed to the three-sentence condition, for example, you will need to successfully write any three sets of words in the two-sentence condition. When you cannot write three sets of words in the three-sentence condition, for example, the task will cease. You will have a practice session where you are given two sets of sentences in the two-sentence condition.

4. Bilingual Dichotic Listening Task

You will hear sixteen pairs of passages. Throughout the task, pay your attention to the preferred ear as indicated in the earedness questionnaire (Experiments 1 and 4) (or non-preferred ear in Experiments 2 and 5). Each pair lasts for one minute. As soon as each audio stimulus ends, you will see five sentence-completion items in the same language as the audio stimulus. So, if you hear English in your preferred (or non-preferred) ear, you will see sentence-completion items in English as well. You are given one minute to answer the questions. Write a word or words, or a number on the dotted line to complete each sentence. The next audio stimulus starts three seconds after the end of presentation of the sentence-completion items. You will not be notified what language you are going to hear next. During the task, you are not allowed to take notes (Experiments 1, 2, and 3) (or encouraged to take notes in Experiments 4, 5, 6, and 7). You will have a practice session to get used to the task.

For Experiments 3, 6, and 7 where attention had to be switched, the following instruction was added: You will be instructed to use one of the ears indicated by an arrow shown on the screen. When you have to attend to your left ear, you will see a left arrow on the left side of the screen (↶), and when you have to attend to your right ear, you will see a right arrow on the right side of the screen (↷), before presentation of the next passage.

B.1: Table 4.4

Table 4.4. *Coefficients (betas), Standard Errors (SEs), and Significant Levels for Generalised Linear Mixed Models of Pairwise Comparisons Between the Eight Conditions (Experiment 2)*

L2 Comprehension				
	REE	REJ	UREE	UREJ
REE	-0.737***	0.256 (0.192) (ns)	0.154 (0.197) (ns)	-0.316 (0.222) (ns)
REJ	-0.256 (0.192) (ns)	-0.481 (0.127)***	-0.102 (0.184) (ns)	-0.572 (0.211)**
UREE	-0.154 (0.197) (ns)	0.102 (0.184) (ns)	-0.582 (0.134)***	-0.470 (0.216)*
UREJ	0.316 (0.222) (ns)	0.572 (0.211)**	0.470 (0.216)*	-1.052 (0.169)***
.....				
RJE	-1.630 (0.158)***	-1.374 (0.142)***	-1.476 (0.148)***	-1.946 (0.181)***
RJJ	-1.549 (0.159)***	-1.293 (0.143)***	-1.395 (0.149)***	-1.865 (0.182)***
URJE	-1.642 (0.158)***	-1.386 (0.142)***	-1.488 (0.148)***	-1.958 (0.181)***
URJJ	-1.614 (0.158)***	-1.358 (0.142)***	-1.459 (0.148)***	-1.929 (0.181)***
WMC	0.086 (0.044)*			
L2 proficiency (residual)	0.004 (0.009)*			
Random Effects	Variance			
Participants	0.001408			

Note. REE: Semantically related English-English texts; REJ: Semantically related English-Japanese texts; UREE: Semantically unrelated English-English texts; and UREJ: Semantically unrelated English-Japanese texts. RJE: Semantically related Japanese-English texts; RJJ: Semantically related Japanese-Japanese texts; URJE: Semantically unrelated Japanese-English texts; and URJJ: Semantically unrelated Japanese-Japanese texts.

* $p < .05$, ** $p < .01$, *** $p < .0001$

Table 4.4. *Coefficients (betas), Standard Errors (SEs), and Significant Levels for Generalised Linear Mixed Models of Pairwise Comparisons Between the Eight Conditions (Experiment 2) (Continued)*

L1 Comprehension				
	RJE	RJJ	URJE	URJJ
REE	1.630 (0.158)***	1.549 (0.159)***	1.642 (0.158)***	1.614 (0.158)***
REJ	1.374 (0.142)***	1.293 (0.143)***	1.386 (0.142)***	1.358 (0.142)***
UREE	1.476 (0.148)***	1.395 (0.149)***	1.488 (0.148)***	1.459 (0.148)***
UREJ	1.946 (0.181)***	1.865 (0.182)***	1.958 (0.181)***	1.929 (0.181)***
RJE	0.893 (0.064)***	-0.081 (0.092) (ns)	0.012 (0.090) (ns)	-0.016 (0.091) (ns)
RJJ	0.081 (0.092) (ns)	0.813 (0.067)***	0.093 (0.092) (ns)	0.064 (0.093) (ns)
URJE	-0.012 (0.090) (ns)	-0.093 (0.092) (ns)	0.906 (0.064)***	-0.029 (0.090) (ns)
URJJ	0.016 (0.091) (ns)	-0.064 (0.093) (ns)	0.029 (0.090) (ns)	0.877 (0.065)***
WMC	0.086 (0.044)*			
L2 proficiency (residual)	0.004 (0.009)*			
Random Effects	Variance			
Participants	0.001408			

Note. REE: Semantically related English-English texts; REJ: Semantically related English-Japanese texts; UREE: Semantically unrelated English-English texts; and UREJ: Semantically unrelated English-Japanese texts. RJE: Semantically related Japanese-English texts; RJJ: Semantically related Japanese-Japanese texts; URJE: Semantically unrelated Japanese-English texts; and URJJ: Semantically unrelated Japanese-Japanese texts.

* $p < .05$, ** $p < .01$, *** $p < .0001$

C.1: Passages and sentence-completion items in the BDL task (Experiments 3, 6, and 7)

In Experiments 3, 6, and 7, pairs of passages presented to the left ear were the same pairs of semantically related passages used in Experiments 1, 2, 4, and 5 (see Appendix A.4). The pairs of passages shown below were another pairs of semantically related passages presented to the right ear (hence, the pairs are numbered between 9 and 16). They were counterbalanced in a Latin square design in the same way as can be seen in Appendix A.5. For the sake of convenience, the attended passages are labelled as I1, I3, J1, J3, K1, K3, L1, and L3, and unattended passages as I2, I4, J2, J4, K2, K4, L2, and L4.

Eight semantically related pairs of passages presented to the right ear (I1 & I2, I3 & I4, J1 & J2, J3 & J4, K1 & K2, K3 & K4, L1 & L2, and L3 & L4)

9. I1 and I2 - LSA: 0.71

Attended passage I1 in English:

A new study has uncovered a link between children's use of public libraries and their literacy skills in school. According to the National Literacy Trust, youngsters who visit their local library are almost twice as likely to be above average readers. Indeed, the research showed that 18 per cent of regular library users read to an above average standard, compared to 9.5 per cent of non-library users. Overall, 44 per cent of children aged between eight and 16 use their local public library and are more than twice as likely to read outside of school as a result. Jonathan Douglas, director of the National Literacy Trust, said the study highlights the important role that libraries play in supporting children's literacy. "In the UK today one in six people struggled to read, write and communicate, which can affect their health, confidence and employability," he remarked. The group organised Save Our Libraries Day on

February 5th to bring to public attention the cuts and closures facing library services in the UK.

Sentence-completion items:

1. There is a link between children's skills and their use of public libraries.
2. Compared to 9.5 % of non-library users,% of library users read more than average.
3. Children between eight and who use public libraries tend to read more than 4..... as much outside of school.
5. Struggling to read, write and communicate can affect health, and employability.

Attended passage II in Japanese:

新しい研究によって、公立図書館の使用と学校での子供の識字能力の関係が明らかになりました。国立識字能力研究所によると、地域の図書館に行く子供の読む能力が、ほぼ平均の2倍高い傾向があることが分かりました。実際、図書館を利用しない人の9.5%に対し、普段から図書館を利用する人は18%が平均値以上読むことが研究で分かっています。全体的にみて、8歳から16歳までの子供の44%は地域の図書館を利用するので、結果的に学校以外で読書をする傾向が2倍以上になります。国立識字能力研究所の所長であるジョナサンダグラスは、「この研究は、図書館が子供の識字能力を支える重要な役割を果たすことを強調している」と述べています。現在のイギリスでは、六人に一人が読み書きと意思疎通を図ることが困難な状態で、それが健康や、自信、そして雇用に影響を与えています。研究所は、大衆の意識をイギリス国内の図書館への予算削減や閉館へ向けるために、2月5日に図書館を守る日を設立しました。

Sentence-completion items:

1. 子供の.....能力と公立図書館使用の間には関係がある。

2. 図書館を使わない 9.5 % の人に比べ、.....% の図書館使用者は平均以上に読書をしている。
3. 8 歳から.....歳の子供で、公立図書館を使う子は学校の外で 4.....以上読む傾向がある。
5. 読み、書き、そしてコミュニケーションが困難であると、健康、.....、そして雇用に影響する。

Unattended passage I2 in English:

A survey of 17,000 children in Great Britain for the National Literacy Trust found they were also twice as likely to read outside class daily. Those reading below the expected level for their age were twice as likely not to use their local libraries, it said. It was based on a survey carried out online through teachers in 112 schools in England, Scotland and Wales with 17,000 8- to 16-year-old pupils. It found that just under half of the children surveyed used their public library. Those that did not go were more than three times more likely not to read outside class and to rate themselves as not very good readers. The most common reason for children not to go to their public library was that their family did not go. The report said: "Family engagement is well understood as a key element in supporting educational achievement, and it seems public library use, as well as being associated with similar positive child outcomes to school library use, has in addition a particularly specialised correlation with family support for reading."

Unattended passage I2 in Japanese:

イギリスで、国立識字研究所が行なった一万七千人の児童を対象にした調査によると、児童は日常的に学校の外で読書をする傾向が2倍あることが分かりました。年齢に対して期待される読書量より読書量が下回る児童は、地域の図書館を使わない傾向が2倍あることも明らかになりました。この調査は、イングランド、スコットランド、そしてウェールズの112の学校の教師を介し、8歳から16歳までの児童生徒17,000人を対象にオンラインで実施されました。それによると、公立

図書館を利用している児童は半分以下しかいないことが分かりました。図書館へ行かない児童は、学校以外では読書をしない傾向が3倍高く、自分たちをあまり読書が上手ではない、と評価していました。公立図書館へ行かない子供の共通した理由は、その子供たちの家族が図書館へ行かないからでした。報告によると、家族の積極的な参加は、子供の学業成績を支える重要な要素であると理解されており、公立図書館の使用は、学校の図書館の利用による成績向上と関連して、読書への家族の支援と特別な相関があるようです。

10. I3 and I4 - LSA: 0.74

Attended passage I3 in English:

It's a disorder that can be embarrassing and even dangerous, but scientists now believe they have discovered one of the secrets behind sleepwalking. Researchers studied four generations of a family where nine members out of 22 had the condition. They found that all the sufferers had a fault on a particular chromosome and carrying just one copy of this defective DNA was enough to cause sleepwalking. The team from Washington University hope the findings will help create new treatments. Sleepwalking affects one in 10 children and around one in 50 adults. If a person with the condition is disturbed during the night, the primitive parts of their brain can spring into life while the conscious controlling part do not. This can cause them to sit up, walk around and complete complex tasks, all while asleep. Those with the condition, also known as somnambulism, may perform benign activities such as pulling on a pair of socks. However, there have been cases where sleepwalkers have been killed after walking into a busy road or they have injured a family member.

Sentence-completion items:

1. Sleepwalking can be embarrassing and rather
2. Among a family studied, out of twenty-two were sleepwalkers.
3. Carrying a copy of a can cause sleepwalking.

4. 10% of children and% of adults are affected by sleepwalking.
5. Sleepwalkers can do complex tasks and have a family member.

Attended passage I3 in Japanese:

恥ずかしく、むしろ危険である病気、夢遊病の謎の一つを科学者が発見したようです。研究者は22人中9人が夢遊病である家族を4世代に渡り研究しました。それによると、全ての夢遊病患者の特定の染色体には欠陥があり、この欠陥のある遺伝子のコピー一つ持っているだけで夢遊病を引き起こすのに充分であることが分かりました。ワシントン大学の研究チームはこれらの発見が新しい治療方法を構築する手助けとなることを望んでいます。子供で10人に1人、大人で50人に1人が夢遊病にかかっています。夢遊病の人が夜間に妨げを受けると、脳の原始的な部位が急に動き出しますが、意識的な制御部位は動きません。これにより眠りながら立ち上がったり、歩き回ったり、複雑な作業をしてしまうのです。夢遊病の人は、害を与えない、例えば靴下をはくということもします。しかしながら、夢遊病の人が車に轢かれてなくなる、または家族を傷つけるといった事件が起きているのです。

Sentence-completion items:

1. 夢遊病は恥ずかしく、むしろ、.....である。
2. 研究された家族のうち、22人中.....人が夢遊病保持者だった。
3.を持っているだけで夢遊病を引き起こす。
4. 子供の10%と大人の.....%が夢遊病に悩まされている。
5. 夢遊病保持者は複雑な作業をすることが出来、家族を.....事件も起こしている。

Unattended passage I4 in English:

Scientists believe they have discovered the genetic code that makes some people sleepwalk. By studying four generations of a family of sleepwalkers they traced the fault to a section of chromosome 20. Carrying even one copy of the defective DNA is enough to cause sleepwalking, the experts told the journal *Neurology*. They hope to target the genes involved and find new treatments for the condition that affects up to

10% of children and one in 50 adults. Most often, sleepwalking is a fairly benign problem and something that will be outgrown. Many children will have episodes where they will arise from their sleep in a trance-like state and wander. But more extreme cases of sleepwalking can be deeply disruptive and downright dangerous, particularly when the condition persists into adulthood. Sleepwalkers may perform complex feats such as locating the car keys, unlocking the doors and then driving. There have even been high-profile cases where sleepwalkers have killed during an episode. Despite this relatively little is known about the phenomenon, called somnambulism by medics.

Unattended passage 14 in Japanese:

科学者は、夢遊病の原因である遺伝子コードを発見しました。夢遊病保持者の家族を四世代に渡って研究した結果、染色体番号20のある部位にある欠陥に辿り着きました。欠陥のある遺伝子のコピーを一つ持っているだけでも、夢遊病を引き起こすのに充分である、と専門家は研究雑誌 神経学で述べています。彼等は夢遊病に関係のある遺伝子に焦点を当て、多くて子供の10%、そして大人の50人に一人に影響を与える夢遊病への新しい治療法を見つけることを望んでいます。夢遊病のほとんどはかなり危険性が少ない問題で、脱することが出来るものでもあります。多くの夢遊病の子供はトランス状態で目覚め、歩き回るでしょう。しかし、もっと厳しい場合は、とても破壊的で危険になり得ます。とくに夢遊病が成人になっても続く場合、そうなります。夢遊病保持者は、車の鍵を探し当て、ドアを開け、運転するというような複雑な芸当をすることもあります。夢遊病状態で殺人を行なうという際立った事件もありました。にも拘らず、医者の中で夢中遊行症と呼ばれる現象について比較的ほとんど分かっていないのです。

11. J1 and J2 - LSA: 0.27

Attended passage J1 in English:

Two US spacecrafts have moved either side of the Sun to establish observing positions that should return remarkable new information about our star. Launched in 2006, the Stereo satellites have gradually been drifting apart - one in front of the Earth in its orbit, the other lagging behind. On Sunday, Nasa said the spacecrafts had arrived at points that put the Sun directly between them. They will give solar physicists the first 360-degree view of our star. STEREO is short for Solar Terrestrial Relations Observatory. The mission is studying the Sun's great explosive events that hurl billions of tonnes of charged particles at Earth - events that can disrupt power grids and satellites. Professor Richard Harrison of the project said, "By being away from the Sun-Earth line, you can look back at the space between the Sun and the Earth and see any of these clouds, these coronal mass ejections - you can even see these things passing over the Earth. Those are the key to what Stereo's all about."

Sentence-completion items:

1. Spacecrafts were launched to bring back new information about the sun.
2. Solar physicists will be able to get a view of the sun.
3. STEREO stands for Solar Terrestrial Observatory.
4. The sun's explosive events can interrupt power grids and
5. Coronal mass can be observed between the sun and the earth.

Attended passage J1 in Japanese:

2つのアメリカの探査機が太陽の両側にそれぞれ移動し、太陽について注目すべき新たな情報を得るための観察位置を確立しました。2006年に打ち上げられたステレオ探査機は一つは地球の軌道の前に、もう一つは後ろに徐々に移動して二手に分かれています。日曜日、NASAは太陽がちょうど真ん中の位置に来るように探査機が移動した、と報告しました。太陽物理学者に初めての太陽の360度の映像

を提供することになります。ステレオとは、太陽と地球の関係探査機の略です。任務は、地球に何十億トンもの帯電した物質を投げつける太陽の巨大な爆破活動を調査することです。その活動は、電気格子や人工衛星を混乱させることもあるのです。プロジェクト担当のリチャード・ハリス教授は、太陽と地球の直線上から離れることによって、太陽と地球の間を観察することが出来、その間の雲、コロナの大量の噴出を観察出来ます。また、これらが地球の上を通っていく様子も見ることも出来ます。これらがステレオ探査機の重要なところ です。

Sentence-completion items:

1. 探査機は太陽の.....新たな情報を得るために打ち上げられた。
2. 太陽物理学者は太陽の.....映像を得ることが出来るようになる。
3. ステレオは太陽と地球の.....探査機の略である。
4. 太陽の爆発活動は電気格子や.....を妨害することがある。
5. コロナの大量の.....は太陽と地球の間で観察される。

Unattended passage J2 in English:

Yesterday, NASA released the first 360-degree images and video of the entire sun after the twin STEREO probes moved into position on opposite sides of our star. The satellites were launched in 2006. "For the first time ever, we can watch solar activity in its full three-dimensional glory," says Angelos Vourlidas of the STEREO science team at the Naval Research Lab. "This is a big moment in solar physics. STEREO has revealed the sun as it really is -- a sphere of hot plasma and intricately woven magnetic fields." Added STEREO (Solar TERrestrial RELations Observatory) program scientist Lika Guhathakurta at NASA headquarters: "With data like these, we can fly around the sun to see what's happening over the horizon — without ever leaving our desks. I expect great advances in theoretical solar physics and space weather forecasting." Back in September, as they were manoeuvring into place, the probes named "Behind" and "Ahead" because of their relative positions in space captured some spectacular solar eruptions.

Unattended passage J2 in Japanese:

昨日、NASAは太陽の360度画像と映像を始めて公開しました。2つのステレオという太陽と地球の関係探査機が、太陽の両側にそれぞれ移動し、撮影しました。その探査衛星は2006年に打ち上げられました。史上初めて、太陽の活動を完全3次元で観察することが出来ます、と海軍研究所のアンジェロ・ヴォーリダスは述べています。これは太陽物理学における重要な出来事です。ステレオ探査機は太陽の本当の姿を明らかにしました。それは、表面の熱いプラズマと複雑に編み込まれた磁場です、とステレオ探査機プログラムの科学者リカ・グハサカルタがNASAの本部で付け加えました。このようなデータを使えば、机を離れずとも太陽の周りを飛んで水平線上で何が起きているのか調べることが出来ます。理論太陽物理学や宇宙の天気予報の大きな進歩を期待しています。昨年9月に探査機が目的地にたどり着いた時、探査機はお互いの宇宙での配置からビハインドとアヘッドと名前が付けられていますが、それらは見事な太陽の噴火をいくつか撮影しています。

12. J3 and J4 - LSA: 0.26

Attended passage J3 in English:

The supersonic vehicle will be powered by a jet engine positioned above a hybrid rocket, a combination which should produce 135,000 horsepower - equivalent to the power of 180 Formula One cars. Engineers at aerospace specialists Hampson Industries in Wigan have now been handed the designs for the car's steel-lattice rear chassis that houses its jet and rocket engines. The Bloodhound will begin runway testing in January next year ahead of going to South Africa to begin its high-speed run programme. The front section of the car will be built by engineers at Advanced Composites Group. Its 900mm diameter wheels, which will be made from an aluminium alloy, will have to withstand rotation in excess of 10,000rpm while simultaneously coping with dirt coming off the lake bed. The land speed record was set by Andy Green in Thrust SSC in 1997 when it reached a top speed of 760mph. More than 4,000 schools are taking part in the team's simultaneous Bloodhound

educational programme. The aim is to inspire pupils to pursue careers in science, engineering, technology and maths.

Sentence-completion items:

1. 135,000 horsepower is equal to the power of F1 cars.
2. The designs are about the car's steel-lattice rear chassis that accommodates its and rocket engines.
3. The of its aluminium wheels is 900mm.
4. The wheels need to be durable enough to handle rapid rotation and dirt from the lake bed
5. Bloodhound educational programme is encouraging students to seek careers in science, engineering, technology and

Attended passage J3 in Japanese:

新しい超音速の車両はハイブリッドロケットの上に設置されたジェットエンジンによって駆動します。そのエンジンは、13万5千馬力を生み出します。それは、180台のF1のパワーに匹敵します。ウィガンにある航空宇宙産業のハンプトン工業のエンジニアは、ジェットエンジンとロケットエンジンを収容する後部車体のデザインを受け取り仕事に取りかかっています。ブラッドハウンドと呼ばれるその車両は、南アフリカでの高速走行プログラムを前に、走行テストを来年の1月に始めます。車両のフロント部分は、アドヴァンスト コンポジット グループのエンジニアによって組み立てられます。アルミ合金で出来た直径90ミリのタイヤは、毎分1万回の回転に耐えると同時に、湖底からはねる泥にも耐えなくてはなりません。陸上走行の最速記録は1997年にスラストSSCのアンディ・グリーンがマークした時速760マイルです。4千以上の学校が、ブラッドハウンド教育プログラムに参加しています。その目的は、生徒・児童を科学、工学、技術、そして数学の道へ進むように促すことです。

Sentence-completion items:

1. 1 3 万 5 千馬力はF1の.....台分に相当する。
2. 設計書は、.....ロケットエンジンを収容する後部車体についてである。
3. アルミで出来たタイヤの.....は9 0 0 ミリである。
4. タイヤは高速回転と湖底からの泥に.....に対処するため十分な耐久性が必要である。
5. ブラッドハウンド教育プログラムは生徒児童に科学、工学、技術、そして.....の道へ進むよう促している。

Unattended passage J4 in English:

Construction work formally begins this week on what is expected to be the world's fastest car. Called Bloodhound, the vehicle has been designed to reach 1,000 mph. The British car will attempt to set the mark as it breaks the land speed record on a dried out lake bed in South Africa's Northern Cape late next year. Bloodhound has been in design for the past three years. It will be powered by a Eurofighter-Typhoon jet engine bolted above a hybrid rocket. The power unit combination should deliver a thrust in the order of 200 kilonewtons. This is not dissimilar to the thrust delivered by one of Concorde's famous Olympus 593 jet engines, except Bloodhound will weigh only about six tonnes. "It's a fantastic feeling to be handing over the drawings to the people who will now build the car," said chief engineer Mark Chapman. The steel-lattice rear chassis will be prepared by aerospace specialists Hampson Industries. They were officially passed the design drawings just a few days ago so that they could start work this week.

Unattended passage J4 in Japanese:

世界最速の車両製作へ向けた正式な建設作業が今週始まります。ブラッドハウンドと呼ばれるその車両は、時速1 0 0 0マイルに達するように設計されました。そのイギリス製作の車両は、来年末に南アフリカのノーザンケープにある乾燥した湖底

で、地上の最高走行速度を破り、新たな記録を打ち立てようとしています。ブラッドハウンドはこの3年間で設計されました。車両は、ハイブリッドロケットの上に設置されたユーロファイター タイフーン ジェットエンジンによって駆動します。動力部分の組み合わせによって、200キロニュートンの推進力を放出するでしょう。これは、ブラッドハウンドが6トンしかないこと以外は、コンコルドの有名なオリンパス593ジェットエンジン1つの推進力と相違ありません。今度はその車両を組み立てる人に設計書を渡すのはなんとも言えない素晴らしい気分だよ、とチーフエンジニアのマーク・チャップマンは述べています。鉄格子の後部車体は、航空宇宙産業の専門家であるハンプソン工業が製造します。彼等は今週作業を開始出来るように、2、3日前に正式に設計書をもらったばかりです。

13. K1 and K2 - LSA: 0.29

Attended passage K1 in English:

A diet of cake, chips and chocolate could adversely impact a child's intelligence, say Bristol University researchers. Their recent study intimates a relationship between a diet high in processed foods and a somewhat reduced IQ. The researchers suggest that poor nutrition can affect brain development. The British Dietetic Association stated that young parents ought to be educated about healthy eating. The researchers confirmed that three kinds of diets emerged: processed diets high in sugar, fat and convenience foods, traditional diets high in potato, meat and vegetables, and health aware diets of fruit, veg, salads and fish. Each child took IQ tests at the age of eight and half. A diet high in processed foods at the age of three was related to a slightly lower IQ at the age of eight and a half. This gives rise to the understanding that it is crucial to ensure that children have a healthy diet right from the beginning, as an unhealthy diet can affect their IQ levels adversely as well as their health.

Sentence-completion items:

1. can be influenced by what children eat.
2. A relationship has been found between IQ and foods.
3. Young British parents need to learn about
4. Researchers found three diets: foods high in sugar and fat, convenience and traditional foods, and foods of fruits, vegetables and fish.
5. The research would indicate that it is to make sure that children eat healthy foods for their brain development.

Attended passage K1 in Japanese:

ケーキ、フライドポテト、そしてチョコレートという食事が子供の知能に悪い影響を与える可能性がある、とブリストル大学の研究者が伝えました。彼等の最近の研究で、加工食品の摂取とIQの低下との間に関係があることが分かりました。研究者は、栄養が乏しいと脳の発達に影響を与える、と示唆しています。英国栄養組合は、若い親は健康的な食事の指導を受けるべきだ、と述べています。研究者は、3種類の食事の仕方があることを確かめました、1つ目は糖分、脂肪分の高い加工食品、2つ目はインスタント食品とジャガイモ、肉、そして野菜が多く含まれている従来の食事、そして3つ目は果物、野菜、サラダや魚などの健康的な食事です。研究で、子供にIQテストを8歳半で受けさせました。3歳の時の加工食品の多い食事の摂取と、8歳半の時のわずかに低いIQとの間に関係が見られました。これにより、不健康な食事は健康だけでなく、IQへも悪影響があるため、生後から健康に注意した食事を取ることを確保することが重要であることへの理解へと繋がるでしょう。

Sentence-completion items:

1. 子供が何を食べるかで.....が影響を受ける。
2. IQと.....食品の間に関係が見つかった。
3. イギリスの若い親は.....について学ぶ必要がある。

4. 研究者は3つの食事の仕方を見つけた：糖分、脂肪分の高い食事、インスタント食品と従来の食事、そして果物、野菜、魚などの.....食事。
5. 研究は脳の発達のために子供が健康な食事をとることが.....であることを示している。

Unattended passage K2 in English:

Children with diets high in fats, sugars and processed foods in early childhood may suffer a lower IQ as they grow. Children who eat chips, biscuits and pizza before the age of three record lower IQ scores five years later than those who have a healthier diets with fruit, vegetables and home-cooked food. The result was irrespective of whether diets improved after the age of three. A study of about 4000 children compared their diets until the age of 8 1/2. A study conducted by Bristol University researchers found the brain grows fastest during the first three years of life. They said it was possible good nutrition during that time "may encourage optimal brain growth." The 20 per cent of children with the worst diet at the age of three had on average an IQ score of 101, which was five points lower than the group eating the best diet by the time they were 8 1/2. with AFP.

Unattended passage K2 in Japanese:

幼年期に脂肪、糖分の高い食事、そして加工食品をとる子供は成長と平行してIQが低くなるかも知れません。フライドポテト、ビスケット、そしてピザを3歳よりも前に摂取する子供は、果物、野菜、そして家庭料理を取る健康的な食事をする子供に比べて、5年後に低いIQを記録することが分かりました。およそ4千人の子供を対象にした研究で、彼等の食事を8歳半になるまで比較しました。ブリストル大学の研究者によって行なわれた研究で生後最初の3年間で脳が最も速く成長することが分かりました。研究者は、その時期に十分な栄養を与えることが脳が最適に成長することを促す可能性がある、と述べています。3歳で最も酷い食事を与えられた子供の20%のIQは、平均で101でした。それは、8歳半までに最も健康な食事を与えられた子供のIQより5ポイント下回っていたのです。

14. K3 and K4 - LSA: 0.27

Attended passage K3 in English:

The secret of the flea's incredible jumping skills has been laid bare by Cambridge researchers who used high-speed video to capture the insects in the act of take-off. The footage shows that the animals catapult themselves into the air by releasing energy stored in the thorax through their leg segments, which in turn push down on their toes. This explosive release of energy propels the fleas upwards at speeds of as much as 1.9 metres per second. Fleas, which weigh less than a gram, can jump around 30cm high. Scientists have debated the finer details of the flea leap since 1967 when a zoologist at Oxford University, discovered that the animals jump by releasing energy stored in a pad made of an elastic protein called resilin. When the Cambridge biologists came by a supply of hedgehog fleas, they decided to study the animals' aerial feats. Evidence from footage of 51 jumps taken by 10 fleas showed that they took off from their toes, rather than their knees, as some previous researchers had suggested.

Sentence-completion items:

1. Researchers used high-speed video to the fleas' jumping skills.
2. Fleas jump at the speed of metres per second.
3. Scientists have been debating the secrets of fleas' jumping skills
since
4. Cambridge biologists investigated fleas.
5. They recorded jumps and found fleas took off from their toes rather
than knees.

Attended passage K3 in Japanese:

蚤の驚異的な跳躍能力の秘密が、ケンブリッジの研究者によって暴かれました。彼等は高速ビデオを使い蚤が跳躍で踏み切る瞬間を撮影しました。撮影された映像は、蚤が胸部に貯めたエネルギーを足に伝わせ、つま先で踏み込み、放出するこ

とで空中へ勢い良く飛び出す瞬間を映しています。この爆発的なエネルギー放出によって、蚤は1秒間に1.9メートルの速さで跳躍します。体重が1グラム以下の蚤は、およそ30センチメートルの高さまで跳躍出来ます。1967年、オックスフォード大学の動物学者が、蚤がレシリンという弾力性のあるタンパク質で出来ている足の裏に貯めたエネルギーを放出することで跳躍することを発見して以来、科学者は蚤の跳躍の詳細について議論を重ねてきました。ケンブリッジの生物学者がハリネズミの蚤を手に入れた際、蚤の空中での妙技を研究することを決めました。10匹の蚤の51回の跳躍の映像によって、以前研究者が主張したように膝ではなく、つま先で跳躍することが分かりました。

Sentence-completion items:

1. 研究者はノミの跳躍能力を.....するために高速ビデオを使用した。
2. ノミは秒速.....メートルで跳躍する。
3. 科学者は.....年以來、ノミの跳躍能力について議論してきた。
4. ケンブリッジの生物学者は.....のノミを調査した。
5.回の跳躍を記録し、ノミは膝ではなくつま先で跳躍することが分かった。

Unattended passage K4 in English:

It took 44 years, a high-speed camera, a scanning electron microscope and a mathematical model, but at last researchers have revealed fleas jump by pushing off with their toes instead of their knees. While it had been known since 1967 how fleas store the energy to leap fast and high, until now there had been a dispute about how they transferred the energy to the ground for lift-off. Supplied with ten adult hedgehog fleas, they filmed 51 jumps by the ten adult fleas. Analysis of the footage revealed the process begins when the flea locks a joint between its body and two hind legs. It then contracts two muscles. This compresses the part of the body that contains an elastic protein called resilin, effectively tensing a biological spring. When the insect releases the spring, energy is transmitted through its leg segments, which act as levers to push down on the toe, equipped with microscopic gripping

claws. The action launches the 0.7 milligram flea at speeds of up to 1.9 metres per second.

Unattended passage K4 in Japanese:

44年の歳月、高速カメラ、X線電子顕微鏡、そして数学的モデルを費やしましたが、研究者は蚤は膝ではなく、つま先を使って跳躍することをようやく明らかにしました。1967年以来蚤が早くそして高く跳躍するためにどのようにエネルギーを貯めるかは分かっていたいますが、どのようにその跳躍のためのエネルギーを地面へ伝わらせるかについては論争がありました。大人のハリネズミの蚤を10匹入手し、研究者は51回の跳躍を映像に記録しました。映像の分析により、跳躍の過程は、蚤がその胴体と日本の後ろ足の間にある関節を固定して始まることを発見しました。そして、次に2つの筋肉を収縮させます。これによりレシリンという弾力性のあるタンパク質を含む体の部分を圧縮し、効率よく生物学的バネを緊張させます。蚤がそのバネを放つとき、エネルギーは微細なかぎ爪のついたつま先で踏み込むための、レバーの役割をする足の節を伝わります。その動きで0.7ミリグラムの蚤は最大秒速1.9メートルで跳躍するのです。

15. L1 and L2 - LSA: 0.15

Attended passage L1 in English:

When men find it hard to work out what women want, blame their hormones. For the ability to read other people's emotions is greatly reduced by testosterone, a study suggests. Boosting the amount of the male sex chemical in women slows their ability to empathise, researchers from Cambridge and Utrecht universities found. Tests also showed that those women with longer ring fingers than index fingers – caused by high testosterone exposure in the womb – are more likely to be affected. Females were tested because they have naturally low levels, meaning any effect of raising the amount could be easily spotted. Cambridge researcher and autism expert Simon Baron-Cohen told the Proceedings of the National Academy of Sciences journal:

‘Small hormonal differences can have far-reaching effects on empathy.’ Dutch researcher Professor Jack van Honk said: ‘We are excited by this finding.’ The results also add weight to a theory that an overload of testosterone in the womb can raise the odds of autism, he added.

Sentence-completion items:

1. Men’s are the cause of their inability to understand women.
2. Male sex chemical injected women’s ability to slows down.
3. Women with longer than ring finger are more affected.
4. Small chemical differences have effects on understanding emotions.
5. The probability of autism can rise due to an overload of testosterone in the

Attended passage L1 in Japanese:

男性が、女性は何を求めているのか分からないとき、それは彼等のホルモンのせいなのです。研究によると、テストステロンによって他人の気持ちを読み取る能力が著しく低下してしまうことが分かりました。男性ホルモンを女性の体内で増やすことにより、共感する能力が下がることがケンブリッジとユトレヒト大学の研究者によって分かりました。その研究は、子宮内でテストステロンにより多くさらされることが原因ですが、人差し指より薬指の長い女性がより影響を受けることも分かりました。女性が研究対象となったのは、女性はもともとテストステロンの量が低く、量を上げた際のどんな影響も容易に見分けることが出来るからです。ケンブリッジの研究者で、自閉症の専門家である、サイモン バロン コーエンは、国立科学学会の学会誌で小さなホルモン量の違いが共感に対して広範囲に影響することがある、と述べました。オランダの研究者である、ジャック バン ホンク教授は、この結果に大変興奮している。この結果は、子宮内で過度な量のテストステロンを浴びることは自閉症になる可能性も上げるという理論の信憑性を高めるとも述べています。

Sentence-completion items:

1. 男性の.....が女性を理解出来ない原因である。
2. テストステロンを注入された女性の.....する能力は低下する。
3.より薬指が長い女性はより影響を受ける。
4. 小さな違いが感情の理解に.....な影響を与える。
5. 自閉症の可能性は.....内のテストステロンの過剰接触により上がる。

Unattended passage L2 in English:

Giving women a small dose of the male sex hormone testosterone makes them less able to empathise with others, say UK and Dutch researchers. Their findings, in journal PNAS, add weight to the theory that the hormone is significant in the development of autism. Sixteen volunteers given testosterone were less able to judge the mood of facial expressions they were shown. Exposure to the hormone in the womb may be key, it is suggested. The latest study, from the universities of Cambridge and Utrecht, tests the idea that the disorder may be the result of an "extreme male brain", perhaps compromised by exposure to male sex hormones during brain development in the womb. In standard tests of "mind-reading", in which subjects look at pictures of faces and try to guess the mood of the person pictured, women tend to do better than men. However, the testosterone dose caused a significant reduction in this "mind-reading" advantage amongst the women. The findings also hinted at the significance of testosterone exposure in the womb.

Unattended passage L2 in Japanese:

女性に少量の男性ホルモンのテストステロンを与えると、女性が他人に共感出来にくくなるということが、イギリスとオランダの研究者により分かりました。国立科学学会の学会誌の中で、彼らの発見によりホルモンが自閉症発達に大きな役割を果たしているという理論に真実みを与えています。テストステロンを投与された16人の実験協力者は、見せられた表情から感情を読み取ることが、より出来なくなっていました。それにより、子宮内でのホルモン接触量が鍵であることを示唆してい

ます。ケンブリッジ大学とユトレヒト大学での最新の研究は自閉症は、恐らく子宮内での脳の発達の際、男性ホルモンにさらされることによって引き起こされた、極端な男性脳が原因であるという理論を調査しています。顔写真を見てその人の感情を予測する、標準のテストでは、女性は男性よりも成績がいい傾向があります。しかしながら、テストステロンの投与によって女性にある、この感情を読むという能力を大きく弱めてしまったのです。この研究結果は、子宮内の大量のテストステロンへの接触が原因であることを示唆しています。

16. L3 and L4 - LSA: 0.34

Attended passage L3 in English:

Almost 12,000 children in England have missed school for at least a month and 1,500 of them cannot be traced, statistics obtained by the Times Educational Supplement reveal. Leicester has the highest number at 2,611 which it said was the result of a "ruthless" process to trace the whereabouts of all children. John Broadhead, head of behaviour and attendance at the council, said other local authorities did not do as much. The next highest is Birmingham with 762. Kent and Bradford have 618 and 593 respectively. The Times asked every local authority how many missing pupils they had recorded and how many of these were traceable. There is no national database, but the last time the government estimated the total, at least four years ago, 10,000 children were thought to be missing. A pupil is counted as missing if they have skipped a month at school. For some, their parents have chosen to teach them at home. Others may be in neighbourhoods where there are not enough school places or may refuse to attend school.

Sentence-completion items:

1. There are about kids missing school.
2. Among the cities studied, Leicester has the highest number of
3. John Broadhead is head of and attendance of the council.
4. A missing pupil is a child who has school for a month.

5. Some children are educated at home by their parents and others may to go to school.

Attended passage L3 in Japanese:

タイムズ教育雑誌で得られた統計によって、イングランドのおよそ1万2千の子供が少なくとも1ヶ月は不登校で、その内1500人が追跡出来ないことが明らかになりました。レスターでは最も多く2611人で、全ての子供の居場所を探すための非常なやり方が原因であると述べています。レスター教育委員会の委員長、ジョン・ブロードヘッドは、他の地域の委員会はそれほど多くない、と述べています。次に不登校が多いのはバーミンガムの762人で、ケントとブラッドフォードは618人と593人です。タイムズ紙は全ての地方自治体に、不登校児童の数とその内何人が追跡出来るかどうか調査しました。全国調査のデータはありませんが、前回政府が見積もった不登校児童の数は、少なくとも4年前で1万人でした。児童が不登校と数えられるのは、1ヶ月学校を休んだ場合です。中には親が家庭教育をしている所もあります。それ以外の児童は、学校数が少ないか、学校へ行くのを拒んでいるのです。

Sentence-completion items:

1. 約.....の不登校児童がいる。
2. 調査対象になった市の中で、レスターの不登校児童数が.....で一番多い。
3. ジョン・ブロードヘッドは教育委員会の.....である。
4. 不登校児童は、1ヶ月学校を.....子供のことを言う。
5. 家庭で親に教育を受ける子供もいるが、学校へ行くのを.....子供もいる。

Unattended passage L4 in English:

Nearly 12,000 children are officially missing from education, figures suggest. Children's charity bosses said the statistic is "deeply troubling," and warned that thousands of vulnerable youngsters could be at risk of harm. The data, obtained by the Times Educational Supplement through Freedom of Information requests, found

that 11,911 children are missing from education. Local authorities were asked how many children are known to them who are not in any kind of education, for example state or private school, or home educated. The figures reveal large urban areas have the highest numbers of youngsters who are not in schooling. Leicester has the highest number, with 2,611 children missing from education. Nine other local authorities - Birmingham, Kent, Bradford, Brent, Sheffield, Southampton, Doncaster and Westminster - each have more than 360 missing children. Sixty-nine local councils claim to have none missing, the figures suggest. Schools have a duty to report back to their local council if a child is absent for 10 or more days continuously. The council then makes inquiries about the child's well-being.

Unattended passage L4 in Japanese:

およそ1万2千人の児童が不登校であることが、統計で明らかになりました。子供の慈善活動の責任者たちはこの統計はとても厄介である、また、何千人もの子供たちが危険にさらされる可能性がある、と警鐘を鳴らしています。情報公開の要求を介し、タイムズ教育雑誌が得たデータで、11,911人の不登校児童がいることが分かりました。どんな形でも教育を受けていない児童数、例えば、公立、私立、もしくは家庭で教育を受けている児童の数を、地方自治体で調査されました。統計によると、大都市の地域で学校教育を受けていない児童がもっとも多いことが分かりました。レスターが最も多く、2611人の児童が学校教育を受けていません。9の他の地方自治体、バーミンガム、ケント、ブラッドフォード、ブレント、シェフィールド、サウザンプトン、ドンカスター、そしてウェストミンスター、でそれぞれ360以上の不登校児童がいます。統計によると、69の地方議会は不登校児童はいないと主張しています。学校は、児童が継続して10日以上休むと地方議会に報告する義務があります。議会は報告を受けた後、その児童の健康状態を尋ねます。

C.2: Table 5.5

Table 5.5. *Coefficients (betas), Standard Errors (SEs), and Significant Levels for Generalised Linear Mixed Models of Pairwise Comparisons Between the Eight Conditions (Experiment 3)*

L2 Comprehension				
	LTEE	LTEJ	RTEE	RTEJ
LTEE	-0.682***	0.038 (0.138) (ns)	0.271 (0.131)*	0.307 (0.130)*
LTEJ	-0.038 (0.138) (ns)	-0.645 (0.102)***	0.232 (0.130) (.)	0.269 (0.129)*
RTEE	-0.271 (0.131)*	-0.232 (0.130) (.)	-0.412 (0.092)***	0.036 (0.121) (ns)
RTEJ	-0.307 (0.130)*	-0.269 (0.129)*	-0.036 (0.121) (ns)	-0.376 (0.090)***
LTJE	-1.396 (0.110)***	-1.358 (0.109)***	-1.125 (0.099)***	-1.089 (0.098)***
LTJJ	-1.292 (0.111)***	-1.254 (0.110)***	-1.022 (0.101)***	-0.985 (0.099)***
RTJE	-1.754 (0.107)***	-1.716 (0.105)***	-1.483 (0.096)***	-1.447 (0.094)***
RTJJ	-1.611 (0.108)***	-1.573 (0.106)***	-1.341 (0.097)***	-1.304 (0.096)***
WMC	0.075 (0.045)(.)			
L2 proficiency (residual)	0.026 (0.011)*			
Random Effects	Variance			
Participants	0.093474			

Note. LTEE: English-English texts with left ear as the attended channel; LTEJ: English-Japanese texts with left ear as the attended channel; RTEE: English-English texts with right ear as the attended channel; and RTEJ: English-Japanese texts with right ear as the attended channel. LTJE: Japanese-English texts with left ear as the attended channel; LTJJ: Japanese-Japanese texts with left ear as the attended channel; RTJE: Japanese-English texts with right ear as the attended channel; and RTJJ: Japanese-Japanese texts with right ear as the attended channel.

(.) $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .0001$

Table 5.5. *Coefficients (betas), Standard Errors (SEs), and Significant Levels for Generalised Linear Mixed Models of Pairwise Comparisons Between the Eight Conditions (Experiment 3) (Continued)*

L1 Comprehension				
	LTJE	LTJJ	RTJE	RTJJ
REE	1.396 (0.110)***	1.292 (0.111)***	1.754 (0.107)***	1.611 (0.108)***
REJ	1.358 (0.109)***	1.254 (0.110)***	1.716 (0.105)***	1.573 (0.106)***
UREE	1.125 (0.099)***	1.022 (0.101)***	1.483 (0.096)***	1.341 (0.097)***
UREJ	1.089 (0.098)***	0.985 (0.099)***	1.447 (0.094)***	1.304 (0.096)***
RJE	0.713 (0.058)***	-0.104 (0.071) (ns)	0.358 (0.064)***	0.215 (0.066)**
RJJ	0.104 (0.071) (ns)	0.609 (0.061)***	0.462 (0.066)***	0.319 (0.068)***
URJE	-0.358 (0.064)***	-0.462 (0.066)***	1.071 (0.052)***	-0.142 (0.060)*
URJJ	-0.215 (0.066)**	-0.319 (0.068)***	0.142 (0.060)*	0.929 (0.054)***
WMC	0.075 (0.045)(.)			
L2 proficiency (residual)	0.026 (0.011)*			
Random Effects	Variance			
Participants	0.093474			

Note. LTEE: English-English texts with left ear as the attended channel; LTEJ: English-Japanese texts with left ear as the attended channel; RTEE: English-English texts with right ear as the attended channel; and RTEJ: English-Japanese texts with right ear as the attended channel. LTJE: Japanese-English texts with left ear as the attended channel; LTJJ: Japanese-Japanese texts with left ear as the attended channel; RTJE: Japanese-English texts with right ear as the attended channel; and RTJJ: Japanese-Japanese texts with right ear as the attended channel.

* $p < .05$, ** $p < .01$, *** $p < .0001$

D.1: Table 6.4

Table 6.4. *Coefficients (betas), Standard Errors (SEs), and Significant Levels for Generalised Linear Mixed Models of Pairwise Comparisons Between the Eight Conditions (Experiment 4)*

L2 Comprehension				
	REE	REJ	UREE	UREJ
REE	-0.401**	0.124 (0.167) (ns)	0.425 (0.156)**	0.150 (0.166) (ns)
REJ	-0.124 (0.167) (ns)	-0.277 (0.116)*	0.301 (0.151)*	0.026 (0.160) (ns)
UREE	-0.425 (0.156)**	-0.301 (0.151)*	0.024 (0.100) (ns)	-0.275 (0.150) (.)
UREJ	-0.150 (0.166) (ns)	-0.026 (0.160) (ns)	0.275 (0.150) (.)	-0.251 (0.115)*
RJE	-1.302 (0.137)***	-1.178 (0.131)***	-0.877 (0.117)***	-1.152 (0.129)***
RJJ	-1.353 (0.136)***	-1.228 (0.130)***	-0.928 (0.116)***	-1.203 (0.129)***
URJE	-1.429 (0.135)***	-1.305 (0.129)***	-1.005 (0.115)***	-1.280 (0.127)***
URJJ	-1.457 (0.135)***	-1.333 (0.128)***	-1.032 (0.114)***	-1.307 (0.127)***
WMC	0.120 (0.058)*			
L2 proficiency (residual)	0.015 (0.008)*			
Random Effects	Variance			
Participants	0.020165			

Note. REE: Semantically related English-English texts; REJ: Semantically related English-Japanese texts; UREE: Semantically unrelated English-English texts; and UREJ: Semantically unrelated English-Japanese texts. RJE: Semantically related Japanese-English texts; RJJ: Semantically related Japanese-Japanese texts; URJE: Semantically unrelated Japanese-English texts; and URJJ: Semantically unrelated Japanese-Japanese texts.

(.) $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .0001$

Table 6.4. *Coefficients (betas), Standard Errors (SEs), and Significant Levels for Generalised Linear Mixed Models of Pairwise Comparisons Between the Eight Conditions (Experiment 4) (Continued)*

L1 Comprehension				
	RJE	RJJ	URJE	URJJ
REE	1.302 (0.137)***	1.353 (0.136)***	1.429 (0.135)***	1.457 (0.135)***
REJ	1.178 (0.131)***	1.228 (0.130)***	1.305 (0.129)***	1.333 (0.128)***
UREE	0.877 (0.117)***	0.928 (0.116)***	1.005 (0.115)***	1.032 (0.114)***
UREJ	1.152 (0.129)***	1.203 (0.129)***	1.280 (0.127)***	1.307 (0.127)***
RJE	0.901 (0.067)***	0.051 (0.089) (ns)	0.128 (0.087) (ns)	0.155 (0.086) (.)
RJJ	-0.051 (0.089) (ns)	0.952 (0.065)***	0.077 (0.086) (ns)	0.105 (0.085) (ns)
URJE	-0.128 (0.087) (ns)	-0.077 (0.086) (ns)	1.028 (0.063)***	0.028 (0.084) (ns)
URJJ	-0.155 (0.086) (.)	-0.105 (0.085) (ns)	-0.028 (0.084) (ns)	1.056 (0.062)***
WMC	0.120 (0.058)*			
L2 proficiency (residual)	0.015 (0.008)*			
Random Effects	Variance			
Participants	0.020165			

Note. REE: Semantically related English-English texts; REJ: Semantically related English-Japanese texts; UREE: Semantically unrelated English-English texts; and UREJ: Semantically unrelated English-Japanese texts. RJE: Semantically related Japanese-English texts; RJJ: Semantically related Japanese-Japanese texts; URJE: Semantically unrelated Japanese-English texts; and URJJ: Semantically unrelated Japanese-Japanese texts.
(.) $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .0001$

D.2: Table 6.15

Table 6.15. *Coefficients (betas), Standard Errors (SEs), and Significant Levels for Generalised Linear Mixed Models of Pairwise Comparisons Between the Eight Conditions (Experiment 6)*

L2 Comprehension				
	LTEE	LTEJ	RTEE	RTEJ
LTEE	-0.179 (0.072)*	0.207 (0.096)*	0.328 (0.094)***	0.177 (0.097) (.)
LTEJ	-0.207 (0.096)*	0.028 (0.065) (ns)	0.121 (0.089) (ns)	-0.029 (0.092) (ns)
RTEE	-0.328 (0.094)***	-0.121 (0.089) (ns)	0.149 (0.061)*	-0.150 (0.089) (.)
RTEJ	-0.177 (0.097) (.)	0.029 (0.092) (ns)	0.150 (0.089) (.)	-0.002 (0.066) (ns)
LTJE	-1.297 (0.081)***	-1.090 (0.075)***	-0.969 (0.071)***	-1.120 (0.075)***
LTJJ	-1.217 (0.081)***	-1.010 (0.075)***	-0.889 (0.072)***	-1.040 (0.076)***
RTJE	-1.214 (0.081)***	-1.007 (0.075)***	-0.886 (0.072)***	-1.037 (0.076)***
RTJJ	-1.331 (0.080)***	-1.125 (0.074)***	-1.004 (0.071)***	-1.154 (0.075)***
WMC	-0.056 (0.023)*			
L2 proficiency (residual)	0.025 (0.005)***			
Exposure (reading in L1)	-0.031 (0.011)***			
Exposure (writing in L1)	-0.031 (0.015)*			
Random Effect	Variance			
Participants	0.0066047			

Note. LTEE: English-English texts with left ear as the attended channel; LTEJ: English-Japanese texts with left ear as the attended channel; RTEE: English-English texts with right ear as the attended channel; and RTEJ: English-Japanese texts with right ear as the attended channel. LTJE: Japanese-English texts with left ear as the attended channel; LTJJ: Japanese-Japanese texts with left ear as the attended channel; RTJE: Japanese-English texts with right ear as the attended channel; and RTJJ: Japanese-Japanese texts with right ear as the attended channel.

(.) $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .0001$

Table 6.15. *Coefficients (betas), Standard Errors (SEs), and Significant Levels for Generalised Linear Mixed Models of Pairwise Comparisons Between the Eight Conditions (Experiment 6) (Continued)*

L1 Comprehension				
	LTJE	LTJJ	RTJE	RTJJ
REE	1.297 (0.081)***	1.217 (0.081)***	1.214 (0.081)***	1.331 (0.080)***
REJ	1.090 (0.075)***	1.010 (0.075)***	1.007 (0.075)***	1.125 (0.074)***
UREE	0.969 (0.071)***	0.889 (0.072)***	0.886 (0.072)***	1.004 (0.071)***
UREJ	1.120 (0.075)***	1.040 (0.076)***	1.037 (0.076)***	1.154 (0.075)***
RJE	1.118 (0.038)***	-0.080 (0.054) (ns)	-0.083 (0.054) (ns)	0.034 (0.052) (ns)
RJJ	0.080 (0.054) (ns)	1.038 (0.040)***	-0.003 (0.055) (ns)	0.114 (0.054)*
URJE	0.083 (0.054) (ns)	0.003 (0.055) (ns)	1.035 (0.040)***	0.117 (0.054)*
URJJ	-0.034 (0.052) (ns)	-0.114 (0.054)*	-0.117 (0.054)*	1.152 (0.038)***
WMC	-0.056 (0.023)*			
L2 proficiency (residual)	0.025 (0.005)***			
Exposure (reading in L1)	-0.031 (0.011)***			
Exposure (writing in L1)	-0.031 (0.015)*			
Random Effect	Variance			
Participants	0.0066047			

Note. LTEE: English-English texts with left ear as the attended channel; LTEJ: English-Japanese texts with left ear as the attended channel; RTEE: English-English texts with right ear as the attended channel; and RTEJ: English-Japanese texts with right ear as the attended channel. LTJE: Japanese-English texts with left ear as the attended channel; LTJJ: Japanese-Japanese texts with left ear as the attended channel; RTJE: Japanese-English texts with right ear as the attended channel; and RTJJ: Japanese-Japanese texts with right ear as the attended channel.

* $p < .05$, ** $p < .01$, *** $p < .0001$

E.1.: Passage presentation orders for Experiment 7

Attended languages in the BDL task in Experiment 7 were switched from L1 to L2 or from L2 to L1 in each ear in a systematic way (i.e., predictable). Four possible presentation orders without repetitions of the same language combinations within ear are shown.

Language switches from L1 to L2:

Subject 1	Attended Ear	Attended Language	Unattended Language
Trials			
1	Left	Japanese	English
2	Right	English	Japanese
3	Left	English	English
4	Right	Japanese	English
5	Left	Japanese	Japanese
6	Right	English	Japanese
7	Left	English	English
8	Right	Japanese	Japanese
9	Left	Japanese	English
10	Right	English	English
11	Left	English	Japanese
12	Right	Japanese	English
13	Left	Japanese	Japanese
14	Right	English	English
15	Left	English	Japanese
16	Right	Japanese	Japanese

Subject 2	Attended Ear	Attended Language	Unattended Language
Trials			
1	Right	Japanese	English
2	Left	English	English
3	Right	English	Japanese
4	Left	Japanese	English
5	Right	Japanese	Japanese
6	Left	English	English
7	Right	English	Japanese
8	Left	Japanese	Japanese
9	Right	Japanese	English
10	Left	English	Japanese
11	Right	English	English
12	Left	Japanese	English
13	Right	Japanese	Japanese
14	Left	English	Japanese
15	Right	English	English
16	Left	Japanese	Japanese

Language switches from L2 to L1:

Subject 3	Attended Ear	Attended Language	Unattended Language
Trials			
1	Left	English	Japanese
2	Right	Japanese	English
3	Left	Japanese	Japanese
4	Right	English	Japanese
5	Left	English	English
6	Right	Japanese	English
7	Left	Japanese	Japanese
8	Right	English	English
9	Left	English	Japanese
10	Right	Japanese	Japanese
11	Left	Japanese	English
12	Right	English	Japanese
13	Left	English	English
14	Right	Japanese	Japanese
15	Left	Japanese	English
16	Right	English	English

Subject 4	Attended Ear	Attended Language	Unattended Language
Trials			
1	Right	English	Japanese
2	Left	Japanese	Japanese
3	Right	Japanese	English
4	Left	English	Japanese
5	Right	English	English
6	Left	Japanese	Japanese
7	Right	Japanese	English
8	Left	English	English
9	Right	English	Japanese
10	Left	Japanese	English
11	Right	Japanese	Japanese
12	Left	English	Japanese
13	Right	English	English
14	Left	Japanese	English
15	Right	Japanese	Japanese
16	Left	English	English

E.2.: Table 7.4

Table 7.4. *Coefficients (betas), Standard Errors (SEs), and Significant Levels for Generalised Linear Mixed Models of Pairwise Comparisons Between the Eight Conditions (Experiment 7)*

L2 Comprehension				
	LTEE	LTEJ	RTEE	RTEJ
LTEE	-0.190 (0.078)*	0.036 (0.110) (ns)	0.174 (0.106) (ns)	0.336 (0.103)**
LTEJ	-0.036 (0.110) (ns)	-0.154 (0.077)*	0.138 (0.105) (ns)	0.299 (0.102)**
RTEE	-0.174 (0.106) (ns)	-0.138 (0.105) (ns)	-0.016 (0.072) (ns)	0.161 (0.098) (.)
RTEJ	-0.336 (0.103)**	-0.299 (0.102)**	-0.161 (0.098) (.)	0.145 (0.066)*
LTJE	-1.311 (0.088)***	-1.275 (0.087)***	-1.137 (0.083)***	-0.976 (0.078)***
LTJJ	-1.311 (0.088)***	-1.309 (0.087)***	-1.171 (0.082)***	-1.010 (0.077)***
RTJE	-1.358 (0.088)***	-1.322 (0.087)***	-1.184 (0.082)***	-1.023 (0.077)***
RTJJ	-1.296 (0.088)***	-1.260 (0.087)***	-1.122 (0.083)***	-0.961 (0.078)***
WMC	0.090 (0.020)***			
L2 proficiency	0.012 (0.005)**			
Exposure (listening in L2)	0.029 (0.013)*			
Random Effect	Variance			
Participants	0.021417			

Note. LTEE: English-English texts with left ear as the attended channel; LTEJ: English-Japanese texts with left ear as the attended channel; RTEE: English-English texts with right ear as the attended channel; and RTEJ: English-Japanese texts with right ear as the attended channel. LTJE: Japanese-English texts with left ear as the attended channel; LTJJ: Japanese-Japanese texts with left ear as the attended channel; RTJE: Japanese-English texts with right ear as the attended channel; and RTJJ: Japanese-Japanese texts with right ear as the attended channel.

(.) $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .0001$

Table 7.4. *Coefficients (betas), Standard Errors (SEs), and Significant Levels for Generalised Linear Mixed Models of Pairwise Comparisons Between the Eight Conditions (Experiment 7) (Continued)*

L1 Comprehension				
	LTJE	LTJJ	RTJE	RTJJ
REE	1.311 (0.088)***	1.346 (0.088)***	1.358 (0.088)***	1.296 (0.088)***
REJ	1.275 (0.087)***	1.309 (0.087)***	1.322 (0.087)***	1.260 (0.087)***
UREE	1.137 (0.083)***	1.171 (0.082)***	1.184 (0.082)***	1.122 (0.083)***
UREJ	0.976 (0.078)***	1.010 (0.077)***	1.023 (0.077)***	0.961 (0.078)***
RJE	1.121 (0.041)***	0.034 (0.057) (ns)	0.047 (0.057) (ns)	-0.015 (0.058) (ns)
RJJ	-0.034 (0.057) (ns)	1.155 (0.040)***	0.013 (0.056) (ns)	-0.049 (0.057) (ns)
URJE	-0.047 (0.057) (ns)	-0.013 (0.056) (ns)	1.168 (0.040)***	-0.062 (0.057) (ns)
URJJ	0.015 (0.058) (ns)	0.049 (0.057) (ns)	0.062 (0.057) (ns)	1.106 (0.041)***
WMC	0.090 (0.020)***			
L2 proficiency	0.012 (0.005)**			
Exposure (listening in L2)	0.029 (0.013)*			
Random Effect	Variance			
Participants	0.021417			

Note. LTEE: English-English texts with left ear as the attended channel; LTEJ: English-Japanese texts with left ear as the attended channel; RTEE: English-English texts with right ear as the attended channel; and RTEJ: English-Japanese texts with right ear as the attended channel. LTJE: Japanese-English texts with left ear as the attended channel; LTJJ: Japanese-Japanese texts with left ear as the attended channel; RTJE: Japanese-English texts with right ear as the attended channel; and RTJJ: Japanese-Japanese texts with right ear as the attended channel.

* $p < .05$, ** $p < .01$, *** $p < .0001$

